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# LIST OF PLATES.

## ERRATUM IN VOL. XV.

**Page 284, Table IV. For Mean Temperature between Latitudes 53° and 54°, *read* 47°·5, *instead of* 46°·5.**

# QUARTERLY JOURNAL

OF THE

# ROYAL METEOROLOGICAL SOCIETY.

VOL. XVI. JANUARY 1890. No. 73.


## SECOND REPORT OF THE THUNDERSTORM COMMITTEE.

### Distribution of Thunderstorms over England and Wales, 1871-1887.


By WILLIAM MARRIOTT, F.R.Met.Soc., Assistant Secretary.



[Read November 20th, 1889.]


IN 1888 the Royal Meteorological Society commenced the collection of systematic observations of Thunderstorms over England and Wales. A large mass of valuable information has already been obtained, which is now being tabulated and plotted on maps ready for discussion. This will afford data for ascertaining the monthly and hourly frequency of thunderstorms, and also for tracing their path across the country.

Some four or five years ago I commenced extracting from *Symons' British Rainfall* and from the Registrar-General's *Quarterly Returns of Births and Deaths* all the dates on which thunderstorms were reported to have occurred at any station in the British Isles. Other duties, however, prevented me from continuing and completing the work. On the appointment of the Thunderstorm Committee, I placed before them the information which I had collected. The Committee considered it desirable that this work for England and Wales should be extended and completed up to the end of 1887. This has now been done, and the results are now submitted.

All the returns from the Society's Second Order and Climatological Stations have been carefully examined, and the dates of the occurrences of thunderstorms extracted. These stations from about 1877 have furnished valuable data, which have formed a good working basis; and with these have been incorporated the dates extracted from the *Observations from Stations of the Second Order* published by the Meteorological Office.

In this investigation only the number of days on which thunderstorms occurred have been dealt with. All notices of thunderstorms, thunder without lightning, lightning without thunder, and sheet, or distant, lightning, have been grouped together as "thunderstorms."

The stations have been arranged according to the Divisions adopted by the Registrar-General of Births and Deaths, the same arrangement as is employed in *Symons' British Rainfall.* There are eleven Divisions, which contain the following Counties:—

| Division. | Counties. |
|---|---|
| I. | Middlesex. |
| II. | Surrey, Kent, Sussex, Hampshire, Berks. |
| III. | Herts, Buckingham, Oxford, Northampton, Huntingdon, Bedford, Cambridge. |
| IV. | Essex, Suffolk, Norfolk. |
| V. | Wilts, Dorset, Devon, Cornwall, Somerset. |
| VI. | Gloucester, Hereford, Shropshire, Stafford, Worcester, Warwick. |
| VII. | Leicester, Rutland, Lincoln, Notts, Derby. |
| VIII. | Cheshire, Lancashire. |
| IX. | Yorkshire. |
| X. | Durham, Northumberland, Cumberland, Westmoreland. |
| XI. | Monmouth, and Wales. |

It will be seen that the Divisions are not by any means of the same size, No. I. consisting only of the small county of Middlesex, while II. and V. together comprise the whole of the South of England. It must be borne in mind that although some of the Divisions may be large, the population is sparse, and consequently there is a great lack of observers. On the whole, however, there has been a fair distribution of stations, the yearly average number of reporting stations for the 17 years being 143, which were distributed as follows:—

| Divisions ... | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of stations | 6 | 26 | 10 | 11 | 27 | 13 | 13 | 8 | 9 | 10 | 10 |

Tables I. to XI. give the monthly and yearly number of days on which thunderstorms or sheet lightning were recorded in each Division during the 17 years, 1871-1887.

The yearly distribution is shown graphically in Fig. 1. The years of greatest frequency were 1880, 1882, 1884, and 1872; and the years of least frequency, 1887, 1874, 1879, and 1871. The most striking feature in

this diagram is the see-saw nature of the curves, years of greater or less frequency alternating regularly throughout nearly the whole of the period.

The average yearly number of thunderstorms is about 39. The Divisions with the greatest yearly frequency are II. with 58·4, V. with 52·3, and X. with 50·1. The Divisions with the least yearly frequency are I. with 17·9, VIII. with 23·6, and IX. with 32·7. (Fig. 3.)

The monthly distribution is shown graphically in Fig. 2. The month

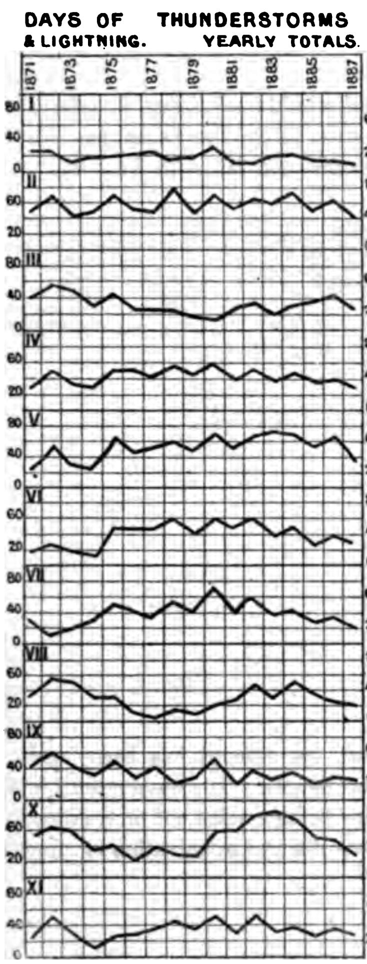


FIG. 1.

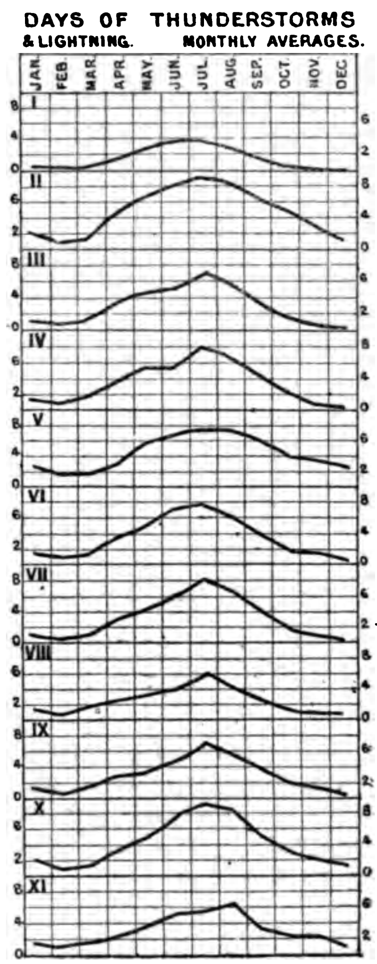


FIG. 2.

with the greatest number of thunderstorms in all Divisions is July, except in Division XI. when it is August. The months with the least number of thunderstorms are February and December. The former month is, however, shorter than the latter by 3 days.

By dividing the year into two halves, viz. April to September, and

October to March, we get the frequency of summer and winter thunderstorms respectively. The figures are as follows:—

| Division. | I. | II. | III. | IV. | V. | VI. | VII. | VIII. | IX. | X. | XI. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Summer ... | 15·9 | 43·7 | 28·8 | 34·1 | 36·0 | 32·3 | 31·9 | 21·9 | 26·0 | 39·0 | 24·6 |
| Winter...... | 2·0 | 14·7 | 6·1 | 7·9 | 16·3 | 7·2 | 5·9 | 6·7 | 6·7 | 11·1 | 8·9 |

The Divisions which have the greatest number of summer thunderstorms are II. with 43·7, X. with 39·0, V. with 36·0, and IV. with 34·1; the Divisions which have the least number are I. with 15·9, VIII. with 21·9, XI. with 24·6, and IX. with 26·0.

The Divisions which have the greatest number of winter thunderstorms are V. with 16·3, II. with 14·7, and X. with 11·1; the Divisions with the least number being I. with 2·0, VII. with 5·9, and III. with 6·1. (Fig. 4.)

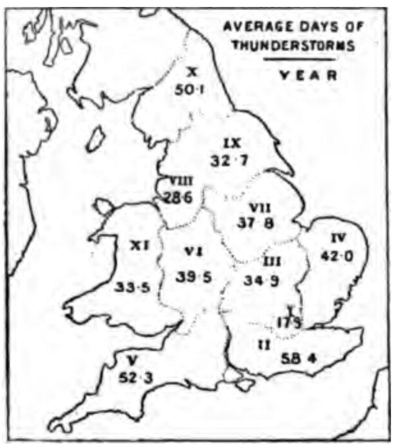


FIG. 3.

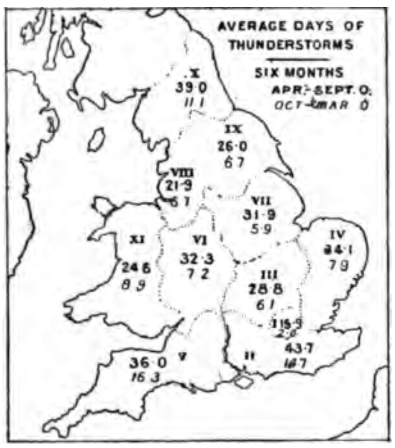


FIG. 4.

This Report being entirely statistical, no attempt has been made to generalise or draw conclusions from the figures. The observations which are now being collected by the Society are being carried out on a systematic plan, and will afford data for a much more detailed examination of thunderstorm phenomena.

## TABLE I.

DIVISION I.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | .. | 1 | 5 | 3 | 9 | 3 | 2 | 1 | 1 | .. | .. | 25 |
| 1872 | .. | 1 | .. | 1 | 3 | 5 | 10 | 3 | 2 | 1 | .. | .. | 26 |
| 1873 | 1 | .. | .. | 2 | 2 | 2 | .. | 2 | 1 | 1 | .. | .. | 11 |
| 1874 | .. | .. | .. | 1 | 5 | 3 | 4 | 2 | 1 | .. | .. | .. | 16 |
| 1875 | .. | .. | .. | .. | 1 | 6 | 2 | 3 | 4 | 2 | .. | .. | 18 |
| 1876 | .. | .. | .. | 3 | .. | 2 | 3 | 4 | 7 | 2 | .. | .. | 21 |
| 1877 | .. | .. | 2 | 3 | 6 | 5 | 4 | 4 | .. | .. | 1 | .. | 25 |
| 1878 | .. | .. | .. | .. | 3 | 3 | 2 | 6 | .. | .. | .. | .. | 14 |
| 1879 | .. | .. | 2 | 1 | 3 | 2 | 3 | 4 | 1 | .. | .. | 1 | 17 |
| 1880 | .. | 2 | .. | 3 | 2 | 5 | 12 | 4 | 2 | 2 | .. | .. | 32 |
| 1881 | .. | .. | .. | 1 | 3 | 1 | 3 | 1 | 1 | .. | .. | .. | 10 |
| 1882 | .. | .. | .. | .. | 1 | 3 | 2 | 2 | 1 | 2 | .. | .. | 11 |
| 1883 | .. | .. | .. | .. | 1 | 6 | 9 | 1 | 1 | .. | 1 | .. | 19 |
| 1884 | 3 | 2 | .. | 3 | 2 | 3 | 3 | 4 | 2 | .. | .. | .. | 22 |
| 1885 | 1 | .. | .. | .. | 4 | .. | 1 | 5 | 3 | 1 | .. | .. | 15 |
| 1886 | .. | .. | 1 | 1 | 3 | 2 | 2 | .. | 1 | 2 | .. | 1 | 13 |
| 1887 | .. | .. | 1 | .. | 2 | .. | 2 | 5 | .. | .. | .. | .. | 10 |
| Totals | 5 | 5 | 7 | 24 | 44 | 57 | 65 | 52 | 28 | 14 | 2 | 2 | 305 |

## TABLE II.

DIVISION II.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | 2 | .. | .. | 5 | 5 | 8 | 11 | 7 | 4 | 5 | 1 | .. | 48 |
| 1872 | 4 | 1 | 5 | 4 | 6 | 7 | 11 | 8 | 5 | 10 | 7 | 2 | 70 |
| 1873 | 8 | .. | 2 | 4 | 2 | 3 | 6 | 5 | 4 | 6 | 3 | .. | 43 |
| 1874 | 1 | 1 | 1 | 2 | 7 | 5 | 9 | 8 | 10 | 2 | 2 | 3 | 51 |
| 1875 | 4 | 1 | .. | .. | 9 | 13 | 7 | 13 | 12 | 8 | 4 | .. | 71 |
| 1876 | .. | .. | 6 | 4 | 1 | 10 | 8 | 8 | 9 | 5 | 2 | 2 | 55 |
| 1877 | 1 | 1 | 3 | 8 | 2 | 7 | 8 | 8 | 2 | 4 | 6 | .. | 50 |
| 1878 | 1 | 1 | .. | 7 | 15 | 12 | 6 | 18 | 5 | 8 | 6 | .. | 79 |
| 1879 | .. | 2 | .. | 5 | 6 | 7 | 9 | 10 | 5 | 2 | .. | 2 | 48 |
| 1880 | 1 | 1 | 1 | 6 | 8 | 10 | 17 | 11 | 7 | 4 | 5 | 1 | 72 |
| 1881 | .. | 2 | .. | 3 | 8 | 9 | 9 | 6 | 7 | 1 | 5 | 2 | 52 |
| 1882 | 1 | .. | 4 | 6 | 8 | 9 | 7 | 6 | 9 | 13 | 3 | .. | 66 |
| 1883 | 2 | .. | .. | 2 | 5 | 16 | 12 | 4 | 7 | 3 | 7 | 1 | 59 |
| 1884 | 3 | 4 | 1 | 5 | 8 | 9 | 16 | 14 | 6 | 5 | .. | 5 | 76 |
| 1885 | 1 | 1 | .. | 3 | 13 | 4 | 4 | 7 | 10 | 5 | .. | 1 | 49 |
| 1886 | 3 | .. | 1 | 9 | 11 | 8 | 9 | 3 | 5 | 9 | 2 | 4 | 64 |
| 1887 | .. | .. | .. | .. | 4 | .. | 8 | 10 | 7 | 3 | 4 | 4 | 40 |
| Totals | 32 | 15 | 24 | 73 | 118 | 137 | 157 | 146 | 114 | 93 | 57 | 27 | 993 |

## TABLE III.

Division III.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | 1 | 2 | 5 | 3 | 4 | 10 | 10 | 4 | 1 | .. | .. | 40 |
| 1872 | 2 | 1 | 2 | 6 | 5 | 10 | 12 | 4 | 7 | 2 | 6 | .. | 57 |
| 1873 | 4 | .. | 2 | 3 | 5 | 4 | 10 | 9 | 4 | 6 | 1 | .. | 48 |
| 1874 | .. | .. | .. | 1 | 5 | 4 | 9 | 4 | 4 | .. | .. | .. | 27 |
| 1875 | 4 | .. | 1 | .. | 5 | 10 | 9 | 7 | 5 | 5 | .. | 1 | 47 |
| 1876 | .. | .. | 2 | 2 | .. | 2 | 4 | 7 | 7 | 2 | .. | .. | 26 |
| 1877 | 1 | .. | 2 | 5 | 5 | 2 | 4 | 5 | 1 | 1 | .. | .. | 26 |
| 1878 | .. | .. | .. | 2 | 6 | 6 | 2 | 7 | 2 | .. | .. | .. | 25 |
| 1879 | .. | .. | 2 | 2 | 3 | 4 | .. | 4 | 2 | .. | .. | .. | 17 |
| 1880 | .. | 2 | 2 | 7 | 2 | 7 | 15 | 6 | 6 | 5 | 1 | 2 | 55 |
| 1881 | .. | 2 | 3 | 3 | 3 | 5 | 3 | 4 | 2 | .. | 1 | 1 | 27 |
| 1882 | .. | .. | .. | 4 | 5 | 9 | 11 | 1 | 3 | 2 | 1 | .. | 36 |
| 1883 | .. | .. | .. | .. | 2 | 10 | 6 | 1 | 1 | .. | .. | .. | 20 |
| 1884 | 1 | 2 | 1 | 2 | 5 | 3 | 7 | 5 | 2 | 1 | .. | 3 | 32 |
| 1885 | .. | 3 | 1 | 4 | 10 | 1 | 3 | 8 | 5 | 2 | .. | .. | 37 |
| 1886 | 1 | .. | .. | 7 | 7 | 4 | 8 | 5 | 3 | 7 | 1 | 3 | 46 |
| 1887 | .. | .. | 2 | .. | 3 | 2 | 7 | 8 | 3 | 1 | 2 | .. | 28 |
| Totals | 13 | 11 | 22 | 53 | 74 | 87 | 120 | 95 | 61 | 35 | 13 | 10 | 594 |

## TABLE IV.

Division IV.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | 1 | 1 | 1 | 7 | 1 | 1 | 7 | 2 | 3 | 2 | 2 | .. | 28 |
| 1872 | 1 | 3 | 2 | 4 | 6 | 1 | 11 | 9 | 8 | 4 | .. | .. | 49 |
| 1873 | 6 | .. | 2 | 2 | 4 | 3 | 2 | 7 | 3 | 2 | .. | .. | 31 |
| 1874 | 2 | .. | .. | .. | 1 | 4 | 9 | 3 | 5 | 1 | 1 | 1 | 27 |
| 1875 | 2 | .. | 2 | .. | 7 | 12 | 9 | 6 | 8 | 2 | 2 | .. | 50 |
| 1876 | .. | 5 | 5 | 6 | 3 | 4 | 8 | 9 | 6 | 3 | .. | .. | 49 |
| 1877 | 5 | 1 | 4 | 6 | 4 | 5 | 7 | 8 | 2 | .. | 1 | .. | 43 |
| 1878 | 1 | .. | .. | 3 | 14 | 7 | 5 | 15 | 4 | 6 | 2 | .. | 57 |
| 1879 | | .. | 3 | 4 | 6 | 11 | 5 | 10 | 4 | 1 | .. | .. | 44 |
| 1880 | .. | 2 | 4 | 6 | 3 | 7 | 19 | 8 | 8 | .. | 1 | 1 | 59 |
| 1881 | .. | 1 | .. | 2 | 7 | 4 | 8 | 8 | 5 | .. | 2 | .. | 37 |
| 1882 | .. | .. | .. | 5 | 3 | 13 | 12 | 9 | 1 | 5 | 2 | .. | 50 |
| 1883 | .. | .. | .. | 1 | 5 | 10 | 10 | 3 | 2 | 3 | 3 | 2 | 39 |
| 1884 | 3 | 2 | .. | 6 | 5 | 3 | 13 | 6 | 5 | 2 | .. | 2 | 47 |
| 1885 | .. | .. | .. | 1 | 13 | 2 | 2 | 6 | 7 | 4 | .. | 1 | 36 |
| 1886 | 1 | .. | 2 | 4 | 7 | 4 | 6 | 3 | 3 | 7 | .. | 2 | 39 |
| 1887 | .. | .. | 2 | 1 | 3 | 2 | 7 | 6 | 5 | 2 | .. | 1 | 29 |
| Totals | 22 | 15 | 27 | 58 | 92 | 93 | 140 | 118 | 79 | 44 | 16 | 10 | 714 |

## TABLE V.

Division V.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | .. | 1 | 1 | 1 | 1 | 2 | 7 | 4 | 5 | 1 | .. | 23 |
| 1872 | 6 | 1 | 1 | 1 | 7 | 7 | 8 | 7 | 6 | 3 | 6 | 3 | 56 |
| 1873 | 5 | 1 | 3 | 1 | 2 | 4 | 4 | 3 | 1 | 4 | 4 | .. | 32 |
| 1874 | 1 | 1 | 2 | 1 | 7 | 3 | 3 | 2 | 5 | 1 | .. | .. | 26 |
| 1875 | 7 | 4 | 1 | 1 | 5 | 11 | 4 | 14 | 10 | 3 | 5 | 1 | 66 |
| 1876 | .. | 2 | 7 | 2 | 3 | 2 | 3 | 9 | 9 | 3 | 2 | 4 | 46 |
| 1877 | 6 | 1 | 4 | 7 | 3 | 5 | 4 | 8 | 1 | 3 | 7 | 2 | 51 |
| 1878 | 2 | .. | .. | .. | 11 | 11 | 7 | 12 | 8 | 4 | 2 | 2 | 59 |
| 1879 | .. | 2 | .. | 5 | 7 | 11 | 7 | 9 | 2 | 1 | 1 | 2 | 47 |
| 1880 | .. | 2 | 1 | 4 | 5 | 7 | 21 | 9 | 6 | 5 | 3 | 6 | 69 |
| 1881 | .. | 3 | .. | 1 | 5 | 7 | 10 | 8 | 8 | 1 | 6 | 4 | 53 |
| 1882 | 2 | .. | .. | 8 | 7 | 9 | 14 | 4 | 5 | 8 | 7 | 3 | 67 |
| 1883 | 3 | 3 | 2 | 1 | 8 | 15 | 15 | 4 | 9 | 3 | 10 | .. | 73 |
| 1884 | 4 | 6 | 2 | 2 | 5 | 9 | 13 | 9 | 7 | 4 | 1 | 6 | 68 |
| 1885 | 2 | 2 | 1 | 1 | 9 | 6 | 1 | 9 | 10 | 8 | .. | 3 | 52 |
| 1886 | 6 | .. | 3 | 12 | 4 | 4 | 4 | 5 | 8 | 9 | 2 | 9 | 66 |
| 1887 | .. | .. | .. | 3 | 5 | 1 | 4 | 5 | 5 | 3 | 6 | 3 | 35 |
| Totals | 44 | 28 | 28 | 51 | 94 | 113 | 124 | 124 | 104 | 68 | 63 | 48 | 889 |

## TABLE VI.

Division VI.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | .. | .. | 2 | .. | 4 | 2 | 6 | 3 | 1 | .. | .. | 18 |
| 1872 | .. | .. | .. | 1 | 3 | 7 | 7 | 5 | 4 | 1 | 2 | .. | 30 |
| 1873 | 4 | .. | 2 | 3 | .. | 3 | 3 | 3 | .. | .. | 1 | .. | 19 |
| 1874 | .. | .. | .. | .. | 2 | 2 | 6 | .. | 1 | .. | 2 | .. | 13 |
| 1875 | 7 | .. | .. | .. | 4 | 10 | 12 | 5 | 5 | 3 | 1 | 1 | 48 |
| 1876 | 1 | 4 | 5 | 5 | 3 | 7 | 6 | 8 | 5 | 2 | .. | 1 | 47 |
| 1877 | .. | .. | 1 | 5 | 10 | 9 | 7 | 8 | 3 | 1 | 3 | .. | 47 |
| 1878 | .. | .. | 1 | 3 | 12 | 12 | 7 | 13 | 3 | 5 | .. | 2 | 58 |
| 1879 | .. | .. | 2 | 4 | 4 | 13 | 5 | 8 | 2 | 2 | 1 | .. | 41 |
| 1880 | .. | 2 | 1 | 6 | 6 | 13 | 17 | 8 | 7 | 1 | 2 | .. | 63 |
| 1881 | .. | .. | 3 | 6 | 6 | 7 | 8 | 10 | 2 | 1 | 6 | .. | 49 |
| 1882 | 1 | .. | 2 | 5 | 9 | 10 | 14 | 6 | 6 | 3 | 2 | 2 | 60 |
| 1883 | .. | 1 | .. | .. | 2 | 10 | 8 | 4 | 4 | 2 | 4 | 1 | 36 |
| 1884 | 3 | 3 | .. | 4 | 6 | 7 | 15 | 4 | 4 | .. | .. | 3 | 49 |
| 1885 | 1 | 1 | .. | 3 | 5 | 2 | .. | 5 | 6 | 2 | 1 | .. | 26 |
| 1886 | 1 | .. | 3 | 7 | 6 | 4 | 3 | 4 | 3 | 3 | 1 | 4 | 39 |
| 1887 | .. | .. | .. | 2 | 4 | 1 | 8 | 5 | 3 | 4 | 2 | .. | 29 |
| Totals | 18 | 11 | 20 | 56 | 82 | 121 | 128 | 102 | 61 | 31 | 28 | 14 | 672 |

## TABLE VII.

Division VII.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | 2 | 2 | 3 | 1 | 5 | 9 | 5 | 1 | 2 | .. | .. | 30 |
| 1872 | 1 | 1 | .. | .. | .. | 1 | 5 | .. | 1 | .. | .. | .. | 9 |
| 1873 | 2 | .. | 1 | 3 | 3 | 4 | 1 | 1 | .. | 1 | 1 | .. | 17 |
| 1874 | .. | .. | .. | 3 | 1 | 3 | 9 | 4 | 7 | 1 | 1 | .. | 29 |
| 1875 | 3 | 1 | .. | 1 | 8 | 13 | 9 | 8 | 5 | 2 | 2 | .. | 52 |
| 1876 | .. | 1 | 3 | 6 | 3 | 5 | 6 | 9 | 8 | 2 | .. | 1 | 44 |
| 1877 | 1 | 1 | 1 | 4 | 5 | 4 | 5 | 8 | 2 | 1 | 1 | .. | 33 |
| 1878 | 1 | .. | 1 | 3 | 11 | 9 | 4 | 17 | 4 | 6 | 1 | .. | 57 |
| 1879 | .. | .. | 2 | 1 | 6 | 10 | 9 | 10 | 2 | 2 | .. | .. | 42 |
| 1880 | .. | 1 | 3 | 11 | 4 | 12 | 20 | 10 | 10 | .. | 1 | 1 | 73 |
| 1881 | .. | .. | 4 | 3 | 4 | 3 | 10 | 6 | 4 | .. | 5 | .. | 39 |
| 1882 | .. | .. | .. | 3 | 10 | 12 | 15 | 10 | 4 | 1 | 3 | .. | 58 |
| 1883 | .. | .. | .. | .. | 4 | 9 | 10 | 2 | 3 | 4 | 2 | 3 | 37 |
| 1884 | 3 | 1 | .. | 4 | 5 | 3 | 14 | 6 | 3 | .. | .. | 2 | 41 |
| 1885 | 1 | 1 | .. | 2 | 7 | 1 | 1 | 5 | 7 | 2 | 1 | .. | 28 |
| 1886 | .. | .. | 2 | 8 | 4 | 2 | 5 | 1 | 2 | 6 | .. | 3 | 33 |
| 1887 | .. | .. | 2 | 2 | 2 | 1 | 5 | 5 | 2 | .. | 1 | .. | 20 |
| Totals | 12 | 9 | 21 | 57 | 78 | 97 | 137 | 107 | 65 | 30 | 19 | 10 | 642 |

## TABLE VIII.

Division VIII.—Number of Days of Thunderstorms (including Sheet Lightning) in each Month, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 187 | .. | 1 | 6 | 2 | 1 | 4 | 9 | 10 | 1 | .. | 3 | .. | 37 |
| 187 | 3 | .. | 2 | 4 | 3 | 11 | 13 | 7 | 9 | 3 | .. | 1 | 56 |
| 1873 | 4 | .. | . | 3 | 5 | 7 | 9 | 8 | 5 | 6 | .. | .. | 47 |
| 1874 | 1 | .. | 2 | 4 | 2 | 1 | 7 | 7 | 5 | .. | .. | .. | 29 |
| 1875 | 2 | .. | .. | 1 | 4 | 5 | 4 | 5 | 5 | 1 | 1 | 1 | 29 |
| 1876 | .. | .. | 3 | 2 | .. | 1 | 2 | 1 | 1 | .. | .. | .. | 10 |
| 1877 | .. | .. | 1 | .. | 1 | .. | 1 | 3 | .. | .. | .. | .. | 6 |
| 1878 | .. | .. | 1 | .. | 5 | 2 | 1 | 5 | .. | 1 | .. | .. | 15 |
| 1879 | .. | .. | 1 | 1 | .. | 4 | 1 | 2 | .. | .. | .. | .. | 9 |
| 1880 | .. | .. | .. | 2 | .. | 6 | 10 | .. | 2 | .. | .. | 1 | 21 |
| 1881 | .. | .. | .. | 1 | 6 | 3 | 5 | 3 | 2 | 1 | 6 | .. | 27 |
| 1882 | .. | .. | 1 | 4 | 9 | 8 | 12 | 3 | 1 | 4 | 5 | .. | 47 |
| 1883 | 1 | 1 | 2 | 2 | 2 | 7 | 5 | 1 | 1 | 3 | 1 | .. | 26 |
| 1884 | 5 | 3 | 2 | 5 | 1 | 2 | 13 | 5 | 5 | 1 | 2 | 5 | 49 |
| 1885 | 2 | 3 | .. | 3 | 10 | 1 | 1 | 4 | 5 | 3 | .. | 2 | 34 |
| 1886 | 2 | .. | 1 | 2 | 3 | 2 | 3 | 1 | 2 | 3 | .. | 6 | 25 |
| 1887 | .. | .. | 1 | 1 | .. | 1 | 4 | 6 | 4 | .. | .. | 2 | 19 |
| Totals | 20 | 8 | 23 | 37 | 52 | 65 | 100 | 71 | 48 | 26 | 18 | 18 | 486 |

## TABLE IX.

DIVISION IX.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | 1 | 1 | 4 | 5 | 3 | 3 | 8 | 10 | 2 | 2 | .. | 1 | 40 |
| 1872 | 4 | .. | 2 | 5 | 7 | 9 | 11 | 8 | 7 | 2 | 3 | 1 | 59 |
| 1873 | 4 | 2 | .. | 2 | 5 | 1 | 8 | 7 | 6 | 6 | 1 | .. | 42 |
| 1874 | 2 | .. | 2 | 2 | 1 | 6 | 7 | 7 | 3 | .. | 1 | .. | 31 |
| 1875 | 2 | 1 | .. | 3 | 5 | 11 | 8 | 8 | 6 | 1 | 1 | 2 | 48 |
| 1876 | .. | .. | 3 | 2 | .. | 4 | 5 | 6 | 2 | 3 | .. | 1 | 26 |
| 1877 | 1 | .. | 2 | 6 | 4 | 5 | 5 | 6 | 2 | 2 | 6 | 1 | 40 |
| 1878 | 1 | .. | .. | .. | 5 | 3 | .. | 5 | 2 | 2 | 3 | .. | 21 |
| 1879 | .. | .. | 1 | 2 | 3 | 6 | 5 | 7 | 1 | .. | 2 | 1 | 28 |
| 1880 | .. | .. | .. | 4 | 1 | 9 | 12 | 3 | 3 | .. | .. | .. | 32 |
| 1881 | .. | .. | 1 | .. | .. | 2 | 5 | 4 | 2 | .. | 3 | 1 | 18 |
| 1882 | .. | .. | 1 | 2 | 3 | 9 | 12 | 1 | 3 | 1 | 4 | .. | 36 |
| 1883 | .. | .. | .. | .. | 2 | 7 | 6 | 4 | 3 | 3 | 1 | 2 | 28 |
| 1884 | 3 | .. | .. | 5 | 1 | 1 | 13 | 7 | 4 | .. | .. | .. | 34 |
| 1885 | .. | .. | .. | 2 | 6 | 1 | 1 | 3 | 5 | 3 | .. | 1 | 22 |
| 1886 | .. | 1 | 1 | 2 | 3 | .. | 5 | 3 | 3 | 7 | 1 | 1 | 27 |
| 1887 | .. | .. | 2 | 3 | .. | .. | 6 | 4 | 5 | 4 | .. | .. | 24 |
| Totals | 18 | 5 | 19 | 45 | 49 | 77 | 117 | 93 | 59 | 36 | 26 | 12 | 556 |

## TABLE X.

DIVISION X.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871–1887.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | .. | 2 | 4 | 2 | 7 | 11 | 14 | 3 | 4 | 4 | 2 | 53 |
| 1872 | 1 | .. | 1 | 3 | 6 | 10 | 14 | 11 | 8 | 5 | 3 | 2 | 64 |
| 1873 | 6 | .. | 1 | 4 | 4 | 8 | 14 | 7 | 6 | 7 | 1 | .. | 58 |
| 1874 | 1 | .. | .. | 3 | .. | 5 | 11 | 6 | 7 | .. | .. | .. | 33 |
| 1875 | 2 | .. | .. | 3 | 3 | 5 | 7 | 6 | 8 | 2 | 2 | 3 | 41 |
| 1876 | .. | .. | 1 | 2 | 1 | 2 | 4 | 5 | 2 | 3 | .. | .. | 20 |
| 1877 | .. | .. | 1 | 4 | 1 | 6 | 6 | 15 | 4 | 1 | .. | 1 | 39 |
| 1878 | 1 | 1 | .. | .. | 9 | 8 | 6 | 6 | .. | .. | 1 | .. | 32 |
| 1879 | .. | .. | .. | 3 | 1 | 8 | 4 | 8 | 3 | .. | 1 | .. | 28 |
| 1880 | 1 | 1 | 1 | 2 | 1 | 15 | 14 | 8 | 9 | 2 | 3 | 1 | 58 |
| 1881 | 4 | .. | 2 | 8 | 9 | 9 | 5 | 7 | 6 | 1 | 6 | 3 | 60 |
| 1882 | 2 | 2 | 1 | 6 | 13 | 14 | 18 | 8 | 3 | 6 | 6 | 2 | 81 |
| 1883 | 1 | 3 | 6 | 5 | 6 | 20 | 10 | 8 | 8 | 8 | 4 | 5 | 84 |
| 1884 | 6 | 3 | 3 | 8 | 8 | 4 | 17 | 11 | 7 | 2 | 3 | 4 | 76 |
| 1885 | 1 | 1 | .. | 2 | 16 | 3 | 7 | 5 | 7 | 8 | 1 | 1 | 52 |
| 1886 | 4 | 2 | 2 | .. | 4 | 4 | 5 | 9 | 4 | 7 | 2 | 5 | 48 |
| 1887 | .. | .. | 1 | 1 | 2 | 4 | 6 | 7 | 3 | 1 | .. | .. | 25 |
| Totals | 30 | 13 | 22 | 58 | 86 | 132 | 159 | 141 | 88 | 57 | 37 | 29 | 852 |

## TABLE XI.

DIVISION XI.—NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH MONTH, 1871-87.

| Date. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1871 | .. | 1 | 3 | .. | 2 | 1 | 5 | 4 | .. | .. | 1 | 1 | 18 |
| 1872 | 4 | .. | 1 | 3 | 1 | 6 | 7 | 8 | 11 | 3 | 6 | 1 | 51 |
| 1873 | 4 | .. | 1 | 3 | 2 | 4 | 4 | 5 | 1 | 3 | .. | .. | 27 |
| 1874 | .. | .. | 1 | .. | 2 | .. | 5 | 2 | 1 | .. | .. | 1 | 12 |
| 1875 | 2 | .. | .. | .. | .. | 3 | 4 | 6 | 6 | 2 | .. | 2 | 25 |
| 1876 | .. | 2 | 3 | 4 | .. | 3 | 2 | 7 | 4 | 3 | .. | .. | 28 |
| 1877 | 2 | 1 | 2 | 1 | 4 | 3 | 5 | 6 | .. | 3 | 9 | .. | 36 |
| 1878 | .. | .. | 1 | 1 | 9 | 6 | 5 | 13 | 3 | 3 | 5 | 1 | 47 |
| 1879 | .. | 2 | .. | 1 | .. | 10 | 2 | 13 | 3 | 3 | .. | 2 | 36 |
| 1880 | .. | 1 | 1 | 2 | 2 | 14 | 14 | 8 | 3 | 3 | 2 | .. | 50 |
| 1881 | .. | .. | 2 | 1 | 5 | 5 | 3 | 5 | 1 | .. | 5 | 2 | 29 |
| 1882 | 1 | .. | 1 | 3 | 8 | 9 | 13 | 5 | 4 | 3 | 5 | .. | 52 |
| 1883 | 1 | .. | 2 | 3 | 3 | 6 | 5 | 2 | 3 | 4 | 3 | .. | 32 |
| 1884 | 2 | 4 | 2 | 1 | 4 | 6 | 7 | 5 | 3 | 1 | 1 | 1 | 37 |
| 1885 | 3 | 2 | 1 | 1 | 3 | 3 | 1 | 7 | 3 | 2 | 1 | 1 | 28 |
| 1886 | 1 | .. | 1 | 5 | 7 | 5 | 3 | 2 | 5 | 2 | .. | 3 | 34 |
| 1887 | .. | .. | .. | 2 | 3 | .. | 4 | 9 | 2 | 4 | 1 | 2 | 27 |
| Totals | 20 | 13 | 22 | 31 | 55 | 84 | 89 | 107 | 53 | 39 | 39 | 17 | 569 |

## TABLE XII.

MONTHLY AVERAGE NUMBER OF DAYS OF THUNDERSTORMS (INCLUDING SHEET LIGHTNING) IN EACH DIVISION, 1871-1887.

| Division. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. | 0·3 | 0·3 | 0·4 | 1·4 | 2·6 | 3·4 | 3·8 | 3·1 | 1·6 | 0·8 | 0·1 | 0·1 | 17·9 |
| II. | 1·9 | 0·9 | 1·4 | 4·3 | 6 9 | 8·0 | 9·2 | 8·6 | 6 7 | 5·5 | 3·4 | 1·6 | 58·4 |
| III. | 0·8 | 0·6 | 1·3 | 3·1 | 4·4 | 5·1 | 7·0 | 5·6 | 3·6 | 2·0 | 0·8 | 0·6 | 34·9 |
| IV. | 1·3 | 0·9 | 1·6 | 3·4 | 5·4 | 5·5 | 8·2 | 7·0 | 4·6 | 2·6 | 0·9 | 0·6 | 42·0 |
| V. | 2·6 | 1·6 | 1·6 | 3 0 | 5·5 | 6 6 | 7·4 | 7·4 | 6·1 | 4 0 | 3·7 | 2 8 | 52·3 |
| VI. | 1·1 | 0·7 | 1·2 | 3·3 | 4·8 | 7·1 | 7·5 | 6·0 | 3·6 | 1·8 | 1·6 | 0·8 | 39·5 |
| VII. | 0·7 | 0·5 | 1 2 | 3·4 | 4·6 | 5·7 | 8·1 | 6·3 | 3·8 | 1·8 | 1·1 | 0·6 | 37·8 |
| VIII. | 1·2 | 0·5 | 1 4 | 2·2 | 3·1 | 3·8 | 5·9 | 4·1 | 2·8 | 1·5 | 1·0 | 1·0 | 28·6 |
| IX. | 1·0 | 0·3 | 1·1 | 2·7 | 2·9 | 4·5 | 6·9 | 5·5 | 3·5 | 2·1 | 1·5 | 0·7 | 32·7 |
| X. | 1·8 | 0·8 | 1·3 | 3·4 | 5·0 | 7·8 | 9·3 | 8·3 | 5·2 | 3·3 | 2·2 | 1·7 | 50·1 |
| XI. | 1·2 | 0·8 | 1·3 | 1·8 | 3·2 | 5·0 | 5·2 | 6·3 | 3·1 | 2·3 | 2·3 | 1·0 | 33·5 |

## DISCUSSION.

Mr. WHIPPLE said, that in a paper read by himself before the Society, in January 1888 (*Quarterly Journal*, Vol. XIV. p. 92), in which he had discussed the information contained in the Symbols Tables published in the *Meteorological Record*, tables would be found similar to those compiled by Mr. Marriott. The material used in his own investigation was much less copious than that which Mr. Marriott had employed, the Symbols Tables only extending from 1878 to 1885. The divisions or districts he had adopted, were those known as the Meteorological Office Districts. It was a pity that this system of districts had not been adhered to by Mr. Marriott, as some comparison between his own results and those contained in the present report could have then been made, but the

adoption of the Registrar General's Divisions made any comparison impossible. He considered it would have been better, in a small territory like the British Isles, if thunderstorms had been treated separately, and occurrences of sheet lightning and distant thunder kept distinct. The occurrence of sheet lightning in a particular district did not necessarily involve that a thunderstorm was experienced there, for it frequently happened that the storm was a long way off. He remembered Mr. Symons quoting an instance in which the reflected lightning of a thunderstorm in progress in the English Channel near the French coast was seen as far distant as the more northern of the Midland counties. He was sorry that so much labour had been devoted to this investigation, and no distinction made between thunderstorms and sheet lightning.

Mr. BRODIE regretted that Mr. Marriott should have adopted for meteorological purposes the districts selected for entirely different uses by the Registrar General. The divisions were doubtless chosen originally with a view to securing a fairly equal distribution of population. The result of the present investigation seemed to show that, the larger the district, the greater number of days with thunderstorms; and the values for the different divisions were therefore in no way comparable. He was also sorry that sheet lightning had been included under the head of thunderstorms, the former being often observed when there was no thunder at all in the neighbourhood.

Mr. SCOTT remarked, in reference to Mr. Brodie's observation regarding sheet lightning, that in his opinion sheet lightning was always the reflection of an ordinary flash, as he did not know what other electrical discharges could occur. A discussion on the subject had taken place at the Vienna Congress, the outcome of which, however, had not been quite in accordance with his (Mr. Scott's) views.

Mr. BUCHAN considered that results had been obtained from Mr. Marriott's discussion which no future observations would alter. The maps clearly indicated the parts of the country subject to winter thunderstorms, and the curves made it plain that July and August were the months of greatest frequency of thunderstorms, there being no decided increase until after the summer solstice. The only true way of discussing such observations was by taking results from individual stations. Regarding the difference of opinion concerning the divisions adopted, it appeared that the Meteorological Office divided the country for one purpose and the Registrar General for another, and it became our duty to discover the best way of dividing the country for the purpose of meteorological investigations. He believed that all distant thunder should be included with thunderstorms, as thunder could not be heard at any great distance, but the inclusion of sheet lightning under the head of thunderstorms was certainly unadvisable, as he was of opinion that 80 per cent. of sheet lightning was unaccompanied by thunder. He then referred to the results of an examination he had made of the observations of lightning at Oxford, and made some remarks concerning the diurnal variation of thunderstorms at this place and on the discordance of the facts deduced from observation with the theories of electricians.

Dr. TRIPE said that the investigation of thunderstorm phenomena was in its infancy, and even the following of wrong methods was not without its use, for it served to show what should be done. The curves clearly illustrated the fact that July was the month of maximum days of thunderstorms in all districts except in Wales, where the maximum occurred in August, and it was possible that the mountainous character of the Welsh districts might have something to do with bringing about this difference. There was no doubt that Middlesex was much too small a division to be compared with the others. The observations collected might, however, be transferred to Divisions Nos. 2 or 3. The number of years discussed rendered the observations more valuable than if a shorter period had been taken, such as that during which our own climatological stations had been at work.

Mr. SYMONS said that he had no idea that the question of divisions would be brought forward, and he was not prepared to discuss there and then the merits of either the Meteorological Office districts or the Registrar General's divisions; but it must be remembered that the former were of comparatively recent formation, whereas the latter date from 1839. As regarded the paper itself, he agreed with the remarks which had been made by Mr. Buchan, with the exception of the one concerning the occurrence of sheet lightning at Oxford. He should much like to know if any special means were taken to watch the weather continuously

from say 6 or 7 p.m., when the staff would probably have ceased routine duties for the day until the next morning, otherwise the increase of recorded occurrences of lightning between 8 and 9 p.m. was possibly due to the fact that the evening observations were taken about these hours, so that conditions would then be favourable for the observation of electrical phenomena. He was sorry sheet lightning had been included under the head of thunderstorms, as lightning was frequently visible over a very large area.

Mr. BUCHAN remarked that he had examined the records of 180 places distributed over the globe in order to ascertain the diurnal variation of the occurrence of thunderstorms, and had found the results obtained corroborated those deduced from the Oxford observations.

Mr. GLYDE remarked that sheet lightning must often occur in the day time, but the light prevented it from being seen. Regarding the distance at which thunder could be heard, he said that he remembered hearing thunder on one occasion, which, according to the ordinary method of calculation, was at least 22 miles distant.

Mr. MAWLEY remarked that if Mr. Marriott's treatment of the observations was as mistaken as it had been said to be, it seemed to him a curious coincidence that the curves for the different districts should support each other so remarkably well as they did in both diagrams.

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# On the CHANGE OF MEAN DAILY TEMPERATURE WHICH ACCOMPANIES THUNDERSTORMS IN SOUTHERN ENGLAND.

By G. M. WHIPPLE, B.Sc., F.R.A.S., F.R.Met.Soc.,

Superintendent of the Kew Observatory of the Royal Society.

[Received October 15th.—Read November 20th, 1889.]

THIS brief communication is submitted to the Royal Meteorological Society as the result of a somewhat cursory examination of the records of the Kew Observatory for the past ten years, 1879 to 1888 inclusive, with the view of investigating the effects of thunderstorms on the local mean daily temperature.

It is very generally quoted as a weather proverb that English climate in summer is made up of sequences of, first three hot days and then a thunderstorm. There is also a widely-spread belief that thunderstorms cool the air. Both these statements now appear to be in great measure fallacious.

Without in any way classifying the storms, either according to season, to their being cyclonic or anticyclonic, line storms or otherwise, the author has taken the Observatory MS. Journals and extracted the dates of the actual storms of thunder and lightning which directly passed over the Kew Observatory, omitting all those cases where the entries were merely those of 'distant thunder,' 'sheet lightning,' or of 'thundery-looking clouds observed.'

This done, the mean temperatures for differences were then taken, and

Table I. formed, in which the following values are given :—In column 1, the date of the thunderstorm ; column 2, the amount of change of mean temperature between that day and the day preceding ; column 3, the similar change between the mean temperature of the two days prior to and the two days subsequent to the storm ; finally, column 4 shows the similar amount of change between the mean of three days before and the mean of the three days after its occurrence.

TABLE I.

CHANGE OF TEMPERATURE ACCOMPANYING THUNDERSTORMS.

| Date. | Change. In 1 day. | In 2 days. | In 3 days. | Date. | Change. In 1 day. | In 2 days. | In 3 days. |
|---|---|---|---|---|---|---|---|
| 1879. May 14.... | —2° | — 3° | — 1° | 1884. June 29.... | —5° | —2° | —1° |
| „ 28.... | +1 | + 2 | + 1 | July 6.... | —4 | 0 | —1 |
| June 24.... | 0 | — 2 | 0 | „ 24.... | —6 | —9 | —7 |
| July 2.... | —1 | — 2 | — 2 | 1885. Jan. 31.... | —4 | —2 | —4 |
| Aug. 2.... | —2 | — 1 | — 3 | May 16.... | —1 | —1 | 0 |
| Dec. 30.... | —6 | + 3 | + 7 | Aug. 6–7 .. | 0 | +3 | +3 |
| 1880. April 6–8 .. | —1 | — 5 | — 6 | „ 20.... | +2 | 0 | —3 |
| July 1.... | —3 | — 4 | — 4 | 1886. April 22.... | —1 | 0 | +3 |
| „ 15.... | 0 | + 2 | + 2 | May 22, 23 | +1 | —4 | —2 |
| „ 21.... | +1 | — 1 | — 1 | June 1.... | +3 | 0 | 0 |
| Sept. 13.... | —3 | — 5 | — 6 | July 25.... | +1 | —4 | —5 |
| 1881. May 28.... | +1 | — 1 | + 1 | Sept. 4.... | +4 | +3 | 0 |
| June 6.... | —4 | —13 | —14 | 1887. May 3... | +5 | +4 | +4 |
| July 5–6 .. | —4 | —13 | —11 | „ 21.... | —4 | —1 | 0 |
| 1882. June 9 .... | —3 | — 2 | — 4 | Aug. 17.... | —2 | —3 | —1 |
| 1883. June 9.... | +1 | + 1 | + 2 | 1888. March 14 .. | +8 | +1 | —3 |
| „ 29, 30 | +7 | + 8 | +11 | April 18–19 | —4 | —5 | —3 |
| July 3.... | —1 | — 7 | — 6 | June 25.... | +7 | —2 | —1 |
| „ 14–15 | —6 | — 3 | — 4 | „ 28.... | —2 | —6 | —9 |
| Aug. 8.... | —4 | — 4 | — 4 | July 5–6 .. | 0 | —4 | —2 |
| 1884. Feb. 11.... | —1 | + 3 | + 4 | „ 16–18 | +4 | +2 | +2 |
| April 3.... | —2 | — 3 | — 1 | „ 22.... | +4 | 0 | —1 |
| „ 27.... | 0 | + 2 | + 3 | „ 30.... | +1 | —4 | —4 |
| May 5.... | —4 | 0 | + 1 | Aug. 30.... | 0 | —1 | —1 |

In all cases a rise of ten ›erature in the interval is indicated by + and a fall by —. The result derived from the discussion of 48 storms in the 10 years is found to be as follows :—

TABLE II.

| Aggregate Change of Temperature in | 1 Day. | 2 Days. | 3 Days. |
|---|---|---|---|
| Rise .......... | +51° | + 35° | + 44° |
| Fall .......... | —80 | —117 | —115 |
| Difference ...... | —29 | — 82 | — 71 |
| Mean .......... | —0°·6 | —1°·7 | —1°·5 |

We have, then, as the general effect of a thunderstorm a reduction of mean temperature of the air of 0°·6 on the day on which it occurs, of 1°·7 two days, and of 1°·5 three days afterwards.

The above figures represent the actual lowering of temperature in the mean, but in order to show how far these facts may be expected to obtain we have prepared the following table:—

TABLE III.

| Number of Cases when the | 1 Day. | 2 Days. | 3 Days. | Total. |
|---|---|---|---|---|
| Temperature rose | 16 | 12 | 13 | 41 |
| " fell | 19 | 30 | 30 | 79 |
| " was constant | 11 | 6 | 5 | 22 |

It may, therefore, finally be concluded that a thunderstorm is accompanied by

A rise of temperature in 29 per cent. of instances
A fall " 56 " "
Does not affect the mean 15 " "

and that, therefore, the proverbs respecting the supposed influence of these electrical phenomena upon the general temperature of the air in the South of England are hardly borne out by the facts, but must be relegated to the lunar influence class of popular sayings.

Incidentally it may be noted that the average number of thunderstorms passing annually over the Kew Observatory is 4·8. In the paper read before the Society in January, 1888,[1] the author, in discussing the weather of England and Wales for the period 1878-1885, obtained 4 as the mean number of thunderstorms annually observed in District V. or Southern England. The difference of 0·8 is probably due to the exceptionally large number in 1888 which increased the average by that amount.

(The observations have been extracted from the register by permission of the Meteorological Council.)

## DISCUSSION.

Mr. Blanford said that, as he understood the author's account of it, the paper did not clearly show whether, and to what extent, thunderstorms had a cooling effect on the atmosphere. Thunderstorms usually occur in the late hours of the afternoon, and in taking the mean temperature of the day the high temperature of the hours preceding the storm is in a great measure neutralised by the coolness that follows. He knew, from experience, that in the Tropics the effect of a thunderstorm upon the temperature of the air is very great, and he had seen the temperature fall 20° in as many minutes on the approach of a storm. The method of comparison of mean temperatures followed by Mr. Whipple did not seem suited to the inquiry, for in order to ascertain the cooling effect of a thunderstorm it would surely be most correct to compare the temperature shortly before the thunderstorm with that registered shortly after the storm had passed, after allowing for the normal diurnal fall of temperature, according to the hour of the day.

Mr. Curtis remarked that in immediate connection with thunderstorms large sudden falls of temperature were frequently recorded by thermographs, and at Kew such falls had been registered which were as large as those described by

[1] *Quarterly Journal*, Vol. XIV. p. 92.

Mr. Blanford. With regard to the method Mr. Whipple had adopted for making his comparison, he considered it was open to grave objection, as it was liable to mask such changes as really did occur.

Mr. BUCHAN described some investigations he had made into thunderstorms experienced in Scotland, mentioning one case in particular in which the rainfall was terrifically heavy over an extremely small area, and stated that he had found that these storms were really very small cyclonic centres, sometimes only amounting to a barometric depression of two or three hundredths of an inch. He had noticed that when the relation between the direction of the wind and the isobaric lines was irregular over a limited area, these thunderstorms should be looked for.

Mr. HUTCHINS said that his experience in Cape Colony certainly seemed to bear out the assertion that after three oppressive hot days a thunderstorm might be expected, followed by a decidedly cooler atmosphere. He had had charge of a thermograph in an eastern part of the Colony, and had often registered temperatures of 100° to 105°, and had seen this temperature reduced to 80° or 75° on the occurrence of a thunderstorm.

Mr. WHIPPLE, in reply, said that the purport of his inquiry had been entirely misunderstood. His results had no connection with temperature changes on the day of the thunderstorm, and the object was really to investigate the truth of the popular idea that after three hot days a thunderstorm would follow, after which the temperature would be cooled down. He had done this, and was now able by means of the figures he had obtained to satisfactorily answer any enquiries or remarks having reference to this generally accepted idea. The figures proved that this notion was hardly correct, for the day's temperature was never lowered more than a couple of degrees, sometimes the decrease only amounted to half a degree, and very frequently there was no decrease whatever. He was perfectly aware that the temperature frequently fell 15° or 20° when a heavy thunderstorm or hailstorm occurred, for in his long experience with thermograms at Kew Observatory he had repeated opportunities of observing such sudden changes in the curves, but with this change of temperature he was not dealing in his paper.

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# NOTE ON AN APPEARANCE OF ST. ELMO'S FIRE

## Seen during a Thunderstorm at Walton-on-the-Naze, on September 3rd, 1889.

BY W. H. DINES, B.A., F.R.Met.Soc.

[Received October 8th.—Read November 20th, 1889.]

DURING the thunderstorm of September 2nd and 3rd, a decided glow was apparent at times upon the metal cross of the Congregational Church, opposite to which I happened to be staying. The cross in question is about 8 ft. above the roof, and 40 ft. to 50 ft. from the ground, and the light seen upon it was similar, both in appearance and intensity, to that of the planet Venus when seen through a slight haze.

Lightning was very frequent throughout the night, but although often within two miles distance, it was not very vivid before 2.30 a.m. on the 3rd. About 3 a.m. it became evident that a very severe storm was occurring a few miles to the southward, and about the same time the light on the cross was first noticed. It appeared perfectly steady and unaffected by the lightning, five

or six flashes of which often occurred within the minute. As the storm came overhead, the light disappeared, or at least could not be seen. I feel certain it really disappeared, but the lightning was so frequent and vivid that it was very difficult to see anything at all between the flashes. As the storm became less severe the light reappeared, but was extinguished for a few seconds by each flash. This continued until daylight, when the phenomenon became invisible.

The metal cross was not an especially prominent point, but it was the only prominent point visible from the window from which I watched the storm. There was no lightning conductor on the chapel, but it was raining hard most of the night, so that there would be fairly good electrical communication with the ground.

Unfortunately, I left Walton early on the morning of the 3rd, and was unable to learn whether any similar appearance had been seen in other parts of the town, or whether much damage had been done by the storm.

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## NOTES ON CIRRUS FORMATION.

By H. HELM CLAYTON, of the Blue Hill Observatory, Mass., U.S.A.

(Communicated by A. LAWRENCE ROTCH, B.Sc., F.R.Met.Soc.)

(Plate I.)

[Received November 4th—Read November 20th, 1889.]

THE following is extracted from the notes and drawings made by the writer, who during the last few years has made a special study of cloud forms and their changes. These notes and drawings were made immediately after the observations, and sometimes after intently watching the slow changes of certain cloud forms for several hours. The observations were all made at the Blue Hill Observatory, unless stated to have been made elsewhere.

*Notes on the formation of Cirrus in a previously cloudless sky.*

On July 2nd, 1888, at 1 p.m., the sky was almost cloudless when cirrus began to appear on the west horizon, and although moving from the north, rapidly extended toward the zenith. At 3 p.m. the cirrus were apparently forming directly overhead. At this time there were some broad cirro-stratus bands in the west extending from 190° azimuth, or almost exactly from north, and diverging from the nearer one of these were a series of cirrus bands radiating from 140° azimuth, or from north-west and extending toward the zenith. These latter were closely watched between 3 and 4 p.m., and new bands and fibres were distinctly seen to form directly overhead. Cirrus fibres would suddenly form at certain points, generally a little east of the eastern end of existing bands, and appear as thin, barely visible, hazy forms, which would rapidly increase in extent and density; while at other

points the cirrus fibres were undergoing no change or were perhaps slowly dissolving. When the observations were begun the ends of the cirrus bands scarcely reached the zenith, but by 4 p.m. the bands extended far beyond the zenith toward the east, although they were moving from slightly east of north. While these formations were going on there were evidently two different currents near together in the upper air, moving with different velocities and in a slightly different direction. At 8 p.m. one portion of cirrus was found moving from 185° with a relative velocity of 8 on the scale used at Blue Hill Observatory; while soon after another portion was found moving from 191° with a relative velocity of 11. Also certain portions of the cirrus were seen to approach others, indicating difference of velocity. About 8.10 to 8.20 p.m. a short, broad band of cirrus, radiating from 190°, formed overhead, and the cirrus fibres in this were apparently those moving with the relative velocity of 11. This band very quickly moved off to the south and disappeared. The cirrus fibres which were formed radiated mainly from the same direction as the bands near the zenith, namely from 140° azimuth. They were not straight, however, but generally somewhat curved or curled, with the ends pointing toward the west. Between 8.30 and 8.50 p.m. there were several varieties of cirrus, namely straight cirrus fibres, cirrus plumes (Plate I., Fig. I. *a*), and cirrus with central bands and fibres diverging at right angles (Fig. I. *b*). The eastern ends of many of the bands were bent toward the south, or in the direction toward which the cirrus were moving. These phenomena seemed to indicate that a rapidly moving current was pushing under another current, and at the plane where the two currents came in contact the air was thrown into little eddies and streams, which at the same time were slowly elevated, and had their moisture condensed into cirrus fibres. Cirrus were observed to form overhead in a somewhat similar manner between 8 and 6 p.m. of April 19th, 1889. Cirrus fibres were also seen to form in a previously cloudless sky at Murfreesboro', Tenn., in the summer of 1888. On this occasion the early morning was cloudless. About 8 a.m. cumuli began to form, and about 9 a.m. a few cirrus fibres appeared near the zenith. These were closely watched, and around them new fibres were seen to be forming, elongating, and interlacing with previously formed fibres, until within a few hours the sky was covered with a network of cirrus.

*The formation of Cirrus bands with cross fibres.*

The writer has also observed the formation of cirrus bands in a previously nearly cloudless sky. On March 31st, 1887, at 2 p.m., cirrus was seen to be forming in the south-west, with the area of formation extending toward the zenith. Between 2 and 8 p.m. the process was closely watched near the zenith, and it was seen that short parallel fibres would first appear (Fig. II. *a*). and then fibres would cross them (Fig. II. *b*). The formation was accompanied by an increase in the relative velocity of the cirrus, and the shorter bands near the zenith were moving from a slightly different direction to the movement of the bands near the horizon. An almost exactly similar process of cloud

formation was observed near the zenith on March 25th, 1888, at 8 a.m. On February 23rd, 1887, at 11 a.m., cirrus were observed which consisted of straight fibres arranged parallel to one another so as to form long bands (Fig. II. *c*). Some of these had cross fibres extending in the direction of the larger axis of the bands; and these were found to be moving in the same direction, but with only about half the velocity of the other fibres, though both were moving with unusual rapidity. Soon after 11 a.m. nearly all of the fibres assumed the direction of the longer axis of the bands, namely from azimuth of 115°, or nearly North-west. At 3 p.m. these were again noticed to be crossed by short transverse fibres, which appeared to be moving in the same direction and with the same velocity.

On December 11th, 1886, a band with cross fibres was observed (Fig. II. *d*). On this occasion, the cross fibres were found to be moving from a direction slightly different to that of the fibres extending in the direction of the long axis of the band, and this was thought to be their cause.

*The formation of Cirrus from cirro-cumulus clouds.*

The formation of cirrus from clouds of the cirro-cumulus or cumulo-cirrus type has been repeatedly observed. The following are some forms observed (Fig. III., *a*, *b*, *c*, *d*, *e*, *f*) :—

These forms apparently all resulted from descending clouds. The heavy particles fell fastest and succeeded one another on account of the less resistance, and thus formed long fibres which were usually carried backward from the cloud on account of the decrease of wind velocity with lower altitude; but in the form "*a*," which was observed at Murfreesboro', Tenn., during the summer of 1882 the fibres hung almost perpendicularly under the cloud. The appearance was the same in all parts of the sky, and evidently not due to perspective. On watching these clouds it is seen that the fibres continuously move outward from the clouds until the entire cloud is drawn out into pure cirrus. In the form "*f*," which was observed August 16th, 1889, the fibres on one side were visibly lower than the cloud, while on the other they were visibly higher. In this case, the cloud was evidently descending into a more rapidly moving current. The lower portions were carried in advance of the cloud, while the upper portions were retarded and drawn out into fibres in the rear of the cloud, so that the cloud assumed the appearance of what has been called "cat's-tail cirrus."

*Cirrus drawn out from cumulus clouds.*

Several times cirrus has been observed to elongate outward from the top of cirro-cumulus clouds, being apparently drawn outward by a more rapid current at the top than at the base of the cirro-cumulus. The following was observed on July 3rd, 1888, and a similar formation of cirrus from the tops of bands of cirro-cumulus has been observed on several previous occasions (Fig. III. *g*) :—

From the top of almost every well-developed shower cloud cirrus fibres may be seen extending. The writer has also repeatedly seen cirrus fibres drawn out from small cumulus clouds. Such clouds were observed on

January 1st and April 16th, 1888, February 13th and 23rd, 1889; and at Ann Arbor, Mich., once in February, and once in April, 1885. On most of these occasions the temperature was low, being near and sometimes below zero Fahr., and this was thought to be the reason why the difference of wind velocity in different portions of the cloud could draw the cloud matter out into long fibres before dissolving by evaporation.

*Notes on the formation of "mare's-tail" cirrus.*

By "mare's-tail" cirrus are meant those which have curved forms (Fig. IV.). On April 12th, 1888, from 7 to 9 a.m., the relative velocity of the cirrus increased from 8 to 18 on the scale used at Blue Hill Observatory, and at 9 a.m. it was noticed that the front ends of all the cirrus bands were bent backward. This suggested that the cause of curved "*mare's-tail*" cirrus was that the current in which the cloud floated moved with a greater velocity than the air immediately in front of it, and as it came in contact with this air was deflected to one side and thus distorted the clouds, giving them a curved appearance. This conclusion appears to have been fully confirmed by subsequent observations. On May 3rd, 1888, the cirrus slightly increased in velocity between 5 and 6 p.m., and at 6 p.m. the front of the cirrus fibres were bent backward. On May 20th, at 7 a.m., the cirrus were curved backward and were evidently increasing in velocity. The relative velocity measured at 7 a.m. was found to be 10; at 7.5 a.m., 12; at 7.15 a.m., 16; and at 7.20 a.m., 17. On May 22nd the cirrus were found alternately curved backward and forward at short intervals of time. No perceptible changes in velocity were measured. On May 24th, between 8 and 9 a.m., the relative velocity of the cirrus increased from 5 to 8. At 8.30 a.m. the front of the cirrus fibres were curved backward. On June 3rd, at 6 p.m., the rear ends of the cirrus were curved forward, and it was found that the cirrus were slowly decreasing in velocity. On June 13th, at 3.30 p.m., cirrus in the east were curved forward, while cirrus in the west were curved backward. At 4 p.m. it was found that cirrus in the east were moving with a relative velocity of 4, while cirrus in the west were moving with a relative velocity of 7.

A number of observations similar to the foregoing have been made.

These curved cirrus, when accompanied by decreasing barometric pressure, frequently indicate that a storm of increasing energy is approaching.

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## DISCUSSION.

THE PRESIDENT (Dr. MARCET), after remarking on the progress of meteorology in the United States of America, and the facilities afforded in that country for the study and elucidation of meteorological questions, inquired whether any accession of relative humidity followed or accompanied the formation of cirri in a clear sky, as he had noticed when on the Peak of Tenerife that the appearance of a small cloud in what had previously been for many days a clear blue sky was followed on the next day by an increase in the relative humidity of the atmosphere.

Dr. TRIPE remarked that the statement in the last paragraph of the paper that the curved cirrus with a falling barometer presaged a storm of increasing energy, hardly accorded with his own observations, for he had several

times noticed that straight, not curved, bands of cirrus, with very thin cloud between each band, and through which the blue sky could be seen, usually foretold the approach of a severe storm.

Mr. WHIPPLE said that the question of cirrus formation had interested him very much for the past three or four years, and he was very pleased to hear Mr. Clayton's paper. The Meteorological Council, about four years ago, had asked the Kew Committee to devote attention to the photography of cirrus clouds, with a view to obtaining some knowledge of their height, rate of travel, &c. Much work was entailed by this inquiry and a considerable number of photographs were taken, but he was afraid hardly any results had been obtained. It frequently happened that, although all haste was made when conditions were favourable to obtain these pictures, all traces of the cirri had disappeared by the time the persons engaged in the work were ready at their posts; and even when pictures of the cloud were obtained, the changes in its form were so rapid that it was very difficult to identify the selected points of cloud in the various photographs taken. He had now set one of his assistants at Kew, who was a fair draughtsman, to sketch the cirri. He was very glad to find that Mr. Clayton had been so successful in describing and drawing the various formation of cirrus.

Mr. ROTCH (replying for Mr. Clayton) said that no relation between cirrus formation and the relative humidity of the atmosphere had been noted, but this could easily be investigated by means of the records of humidity registered at hourly intervals at the Blue Hill Observatory. However, it did not appear probable that the conditions near the ground would be affected by cloud formation at the height at which cirrus was believed to be, and that such variations in the humidity of the upper air might be better detected by means of the rain-band spectroscope.

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# A COMPARISON BETWEEN THE JORDAN AND THE CAMPBELL-STOKES SUNSHINE RECORDERS.

By F. C. BAYARD, LL.M., F.R.Met.Soc.

[Received July 10th.—Read November 20th, 1889.]

SOMETIME ago, in the discussion following Mr. Jordan's paper on his new pattern Sunshine Recorder (*Quarterly Journal*, Vol. XIV. p. 212), I was enabled by the courtesy of Messrs. Negretti and Zambra to produce a certificate of comparison of one of Mr. Jordan's instruments with the Campbell-Stokes Recorder at the Kew Observatory. This certificate seemed to show that the monthly records, though not the daily ones, of the two instruments were practically identical. As I had had the Jordan instrument since April 1885, I had myself come to the conclusion that the Jordan registered more than the burning recorder.

The discussion on Mr. Jordan's paper gave me the impression that a comparison of the two instruments extending over some months and with a similar exposure might prove of some value. I therefore had a strong scaffolding pole, 15 feet high, erected in my garden at Wallington. On the top of this pole was a shelf properly levelled, on which was placed a 'universal burning' Recorder kindly lent by Messrs. Negretti and Zambra for the pur-

pose of the investigation. Nine inches below this top shelf I had another shelf constructed facing south and duly levelled, on which I placed the old pattern Jordan sunshine recorder. The two recorders were placed true north and south. The observations commenced on June 1st, 1888, and terminated on May 31st, 1889, and there are a complete year's records with the exception of the last 4 days in August 1888, the first 5 days in September 1888 (during which time I was away for a holiday), and September 27th, 1888, when I unfortunately put a wrong card into the burning recorder and so failed to get a trace, though I had 9·6 hours in the Jordan recorder.

Having commenced the observations, my next proceeding was to decide whether I would read the Jordan records before fixing them in water or after fixing. I decided to read them as I had hitherto done, before fixing, for I had found by long experience that the lighter traces disappeared in the process of fixing. This method of reading has one disadvantage, and a most important one, namely, that it is impossible for anyone to verify the reading made by the observer. This disadvantage I have endeavoured to minimise as much as possible by reading the papers myself. On the papers and the cards every trace has been read.

During the observations, and indeed some time previously, I found that there were defects so to speak in both instruments ; these I will now mention, in order to show that I have not forgotten them. With respect to the burning recorder, it does not act at all when there is dew or water on the ball, for the ball must be quite dry before the rays penetrate it, and this defect is more especially noticeable in the morning and evening, and also after heavy showers ; as far as my observations go it matters very little whether the cardboard slip is wet or dry, for when the rays once get through the ball they char the paper.

With respect to the Jordan there are two defects, or rather one defect, which is attributable to the rain ; if the rain drives at all it goes in at the hole facing the direction of the rain, and runs down the paper, spoiling it wherever it touches and forms a pool in the bottom of the drum, out of which I have several times taken as much as a teaspoonful of water ; also a drop of rain sometimes falls on a hole, and without penetrating the drum it causes "a blur" on the paper which it is impossible to read. It is a curious circumstance that most of the cases in which the burning records were more than the Jordan are due to rain. It is possible that these defects in each instrument may be in a great measure neutralised by covering the instrument with a bell-glass or an ordinary glass shade, a method which I have not tried owing to the very exposed position of the instruments.

I will now endeavour to deal with the observations on the subject. The Jordan instrument recorded as much or more than the burning one on every day except on June 20th and 28th, July 1st, 26th and 30th, August 2nd, 5th and 13th, September 10th and 30th, October 5th, 7th and 13th, November 4th, February 2nd, 4th, 20th and 23rd, March 25th, and May 2nd, in all 20 days out of the 365 days on which the observations were taken. The excess of the burning recorder on no occasion exceeded one hour,

which amount was only reached on two occasions, viz. September 30th and October 5th. These differences are caused partly by rain and damp, and partly by a bad light which affects the actinic more than the burning rays. On the other hand, the excess of the Jordan over the burning instrument is very great, being as much as 5·2 hours on June 3rd, 1888, and 4·5 hours on May 1st and 3rd, 1889. The monthly excess of the Jordan over the burning recorder has in the following table been expressed in the form of a percentage, in which the burning one has been considered as the standard.

INCREASE PER CENT. OF SUNLIGHT OVER BRIGHT SUNSHINE.

| 1888. | Sunlight. | Bright Sunshine. | Percentage of Increase. |
|---|---|---|---|
| June (30 days) | 125·6 | 100·0 | 25·6 |
| July (31 days) | 125·1 | 100·0 | 25·1 |
| August (27 days) | 112·4 | 100·0 | 12·4 |
| September (24 days) | 108·4 | 100·0 | 8·4 |
| October (31 days) | 115·7 | 100·0 | 15·7 |
| November (30 days) | 136·8 | 100·0 | 36·8 |
| December (31 days) | 147·9 | 100·0 | 47·9 |
| 1889. | | | |
| January (31 days) | 161·4 | 100·0 | 61·4 |
| February (28 days) | 129·1 | 100·0 | 29·1 |
| March (31 days) | 127·9 | 100·0 | 27·9 |
| April (30 days) | 140·6 | 100·0 | 40·6 |
| May (31 days) | 125·5 | 100·0 | 25·5 |
| | | | Mean Percentage of Increase 29·7 |

If one looks carefully at the above table it seems to present a most remarkable result, and it gives one the impression that the subject is well worthy of further systematic observations extending over a considerable period of time. There seem as it were to be two maxima, one in January, 61·4, and the other in April, 40·6; and two minima, one in September, 8·4 (this is rather doubtful, as 6 days are wanting), and the other in March, 27·9.

In indicating these results I wish to call attention to the necessity of further investigation into the properties of these two sunshine recorders; and this brings me back to the certificate mentioned in the beginning of this paper. I believe that the readings given in this certificate are correct, but that the Jordan papers were read after the fixing of the trace by water, and not before. A look at the papers and cards which I have placed in the library of the Society shows this fairly conclusively. It therefore comes to this, that the Society, before publishing the records of the Jordan, should also decide not only to publish the records in italics, as is done, but also should say whether the papers are read before or after fixing, for the monthly though not the daily values of the Jordan will be fairly comparable with the burning recorder if the papers are read after fixing, but not so if they are read before.

## DISCUSSION.

Mr. JORDAN said that, in designing the photographic sunshine recorder, his endeavour was to produce an instrument capable of registering the exact time during which the sun's direct rays are strong enough to cast well-defined shadows of opaque objects, and he thought that the best form of the instrument accomplishes this result, and that the whole of such sunshine is recorded and no more; in fact, it cannot, from the nature of its construction, register *too much* sunshine. Mr. Bayard, in his paper, pointed out very clearly and correctly the relative defects of the two instruments he used; but he (Mr. Jordan) regretted very much that the old original form of photographic recorder was selected for comparison with the burning instrument. He referred to this more particularly with reference to the suggested further investigation of the subject, and because a few words of explanation would make it clear that the defects pointed out in his early recorder have been entirely obviated and guarded against in the recently altered form of the instrument. Mr. Bayard observed, with respect to the "Jordan" recorder, that two defects are noticeable in times of rain, which in stormy weather, he says, is driven into the apertures, and running down the paper, spoils its sensitiveness, and that he has often found a pool of water at the bottom of the drum. Again a drop of rain sometimes falls on an aperture, and if sunshine immediately follows, the record is so blurred that it cannot be read. He (Mr. Jordan) was quite ready to admit that the single cylinder form of the instrument used by Mr. Bayard had in a measure these defects; but in the double-chambered recorder (described in the *Quarterly Journal*, Vol. XIV. p. 212) the conditions are so altered as entirely to avoid them. In the first place, the apertures are situated in the flat side of the chamber, with which the chart does not come into contact, so that water, if it enters, cannot run down over it. And again, the apertures themselves are cut in separate discs of metal, which project above the surface, to which they are fixed (instead of being cut in the bottom of hollows filed on the outer surface of the cylinder, as in the original instrument). By these simple means any water falling on the instrument drains off on either side instead of being conducted into the apertures. It is, of course, just possible that in very heavy rain and wind a few drops falling directly on the apertures may enter the instrument, but it is only in fine splashes, which rarely, if ever, interfere with the record or spoil the sensitiveness of the paper. It would not be desirable to screen the instrument with a glass shade, as suggested, because that would introduce into the photographic system the most serious defect of the burning system by presenting a surface capable of accumulating dew and hoar frost, which in winter so seriously interfere with the working of the Campbell instrument. With respect to the washing out of the trace in the process of fixing, he found that, in the sensitised charts now supplied by Messrs. Negretti and Zambra, there is scarcely any appreciable difference before and after fixing. Of course the papers must not be left too long in water; they need only be just washed for a few seconds, in order to dissolve away the sensitive portions of the preparation which have not been acted on by the sun's rays. It is better if the charts are not used too fresh; after being sensitised, they should be kept for a few days before being used. With regard to the character of the respective traces produced by the two instruments in registering alternate periods of sunshine and cloud, he said that, on close examination of the photographic trace, it will be noticed that the record appears in well-defined indications in comparison with the burnt trace, where (under similar conditions) the effect of burning scorches the card for a considerable distance around the centre of the burn, frequently overlapping the intervals produced by passing clouds, and giving the effect of a continuous trace. In such cases it is quite possible to count up more sunshine for the Campbell instrument than would be recorded by the photographic method; and this may, perhaps, in some measure have accounted for the excess of sunshine registered by the Campbell instrument over that of the Jordan in the comparison made at the Kew Observatory referred to in Mr. Bayard's paper.

Mr. WHIPPLE, in reply to Mr. Bayard's inquiry, stated that at Kew the Jordan Sunshine Recorder sheets were fixed, washed, and dried before being tabulated.

Mr. CURTIS inquired what was the character of those portions of the traces which were lost in "fixing" the record of the Jordan recorder, and suggested that they must have been extremely faint to be so readily removed. He questioned very much whether it was allowable to regard such faint traces as being really due to actual bright sunshine, and if they had been disregarded he thought the records of the two instruments would probably not have differed very much. The statement, that the lens of the Stokes instrument being simply wet prevented its action, did not agree with his experience; hoar-frost would, of course, do so, but not a film of water.

Mr. BAYARD said that he had used the old pattern of the Jordan Recorder because the new form of instrument was not available when the comparison was commenced. The lighter traces of the Jordan records which became invisible after fixing the paper in water, appeared to be of the same character as the strong traces, and their outline was just as sharply defined, the only difference being in the shade of the trace.

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# CLIMATOLOGICAL OBSERVATIONS AT BALLYBOLEY, CO. ANTRIM.

By S. A. HILL, B.Sc., F.R.Met.Soc.

(Abstract.)

[Received September 6th.—Read November 20th, 1889.]

THE observations summarised below were made once a day at 8.30 a.m. by Mr. Thomas H. Craig, with duly-verified instruments, the air temperatures being taken in a Stevenson's screen 4 ft. above the ground, and the rain gauge being 1 ft. 4 in. above the soil. The exact spot where they are made is lat. 54°43′ N and long. 5°59′ W, in the Townland of Ballyboley, close to the Ballyclare Junction of the Larne and Ballymena Railway, near the foot of the steep slope between Cairn-an-Ard and the watershed between the Larne and the Six-Mile Water. The height above sea level is between 400 ft. and 450 ft. The observations are complete for the 5 years 1884-88, with the exception of the maximum temperature in the shade for January 1884, the value for which has been estimated by differentiation from readings at adjacent stations.

The highest air temperature recorded during the period under observation was 80°, and the lowest 14°. The range of the monthly means was only 19°·7. The months of June, July and August were free from frosts during the whole period, and only one frosty night was observed in September. Frosts are more frequent in the bottom of the valley, for, owing to the slope of the ground, the air cooled by nocturnal radiation flows down and collects there.

With respect to the rainfall, notwithstanding the low mean temperature, snow does not usually fall on more than 10 days during the year. Large falls are scarce, and, during the period, the three largest occurred in the year

1888, viz. 1·60 in. on May 29th, 1·80 in. on July 28th, and 1·68 in. on December 18th.

Table I. comprises a summary of the Temperature observations, and Table II. a summary of the Rainfall observations.

TABLE I.

AIR TEMPERATURES, 1884–1888.

| Months. | Means. | | | Extremes. | | | | Means at 8.30 a.m. | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Mean. | Max. | Year. | Min. | Year. | Dry. | Wet. | Relative Humidity. |
| | ° | ° | ° | ° | | ° | | ° | ° | o/o |
| January .. | 42·0 | 33·6 | 37·8 | 54·0 | 1888 | 14·0 | 1887 | 37·9 | 37·4 | 96 |
| February .. | 42·7 | 33·2 | 38·0 | 55·0 | 1885 | 22·0 | 1885 | 37·7 | 36·7 | 91 |
| March .... | 44·5 | 32·9 | 38·7 | 60·0 | 1887 | 18·0 | 1888 | 37·9 | 37·0 | 92 |
| April .... | 51·0 | 36·2 | 43·6 | 68·0 | 1886 | 27·0 | 1887<br>1888 | 43·2 | 41·3 | 85 |
| May ...... | 56·7 | 40·6 | 48·7 | 69·0 | 1884 | 29·0 | 1887 | 49·5 | 46·5 | 79 |
| June .... | 62·5 | 46·5 | 54·5 | 80·0 | 1887 | 37·0 | 1885<br>1888 | 54·8 | 52·5 | 85 |
| July ...... | 65·1 | 49·6 | 57·4 | 80·0 | 1885 | 37·0 | 1887 | 56·1 | 54·2 | 87 |
| August .. | 63·5 | 49·1 | 56·3 | 76·0 | 1884 | 37·0 | 1885<br>1887 | 56·7 | 54·6 | 87 |
| September | 59·5 | 46·0 | 52·7 | 71·0 | 1884 | 35·0 | 1887 | 52·5 | 51·3 | 91 |
| October .... | 52·0 | 40·5 | 46·3 | 65·0 | 1886 | 30·0 | 1887 | 45·9 | 44·5 | 89 |
| November .. | 46·3 | 37·1 | 41·7 | 57·0 | 1885 | 24·0 | 1887 | 42·0 | 41·2 | 93 |
| December .. | 42·2 | 33·1 | 37·7 | 55·0 | 1888 | 14·0 | 1886 | 37·2 | 36·7 | 95 |
| Mean .. | 52·3 | 39·9 | 46·1 | .. | . | .. | .. | 46·0 | 44·5 | 89 |

TABLE II.

RAINFALL, 1884-1888.

| Months. | Totals. | | | | | Means. | |
|---|---|---|---|---|---|---|---|
| | 1884. | 1885. | 1886. | 1887. | 1888. | 1884 to 1888. | No. of Days on which ·01 fell. |
| | In. | In. | In. | In. | In. | In. | |
| January ...... | 6·55 | 2·53 | 5·31 | 2·78 | 2·30 | 3·89 | 17 |
| February ...... | 3·17 | 4·39 | 2·42 | 1·60 | 0·84 | 2·49 | 15 |
| March ........ | 4·68 | 2·25 | 2·24 | 1·49 | 3·96 | 2·92 | 16 |
| April ........ | 2·26 | 3·63 | 2·42 | 1·65 | 1·15 | 2·22 | 12 |
| May .......... | 2·27 | 2·19 | 3·00 | 2·11 | 3·99 | 2·71 | 15 |
| June .......... | 1·37 | 0·74 | 1·52 | 0·49 | 3·64 | 1·56 | 9 |
| July .......... | 3·11 | 2·20 | 3·01 | 2·71 | 6·92 | 3·59 | 16 |
| August ........ | 2·57 | 2·75 | 2·56 | 2·35 | 3·84 | 2·81 | 15 |
| September .... | 3·51 | 5·22 | 3·51 | 4·13 | 1·73 | 3·62 | 15 |
| October ........ | 2·66 | 4·15 | 5·00 | 1·98 | 1·87 | 3·13 | 15 |
| November ...... | 3·41 | 2·36 | 4·13 | 2·85 | 2·16 | 3·78 | 16 |
| December .... | 4·18 | 2·00 | 5·46 | 2·97 | 2·27 | 3·58 | 16 |
| Totals ...... | 39·74 | 34·41 | 40·58 | 27·11 | 39·67 | 36·30 | 177 |

# Report of the Wind Force Committee on the Factor of the Kew Pattern Robinson Anemometer.

DRAWN UP BY W. H. DINES, B.A., F.R.Met.Soc.

[Read December 18th, 1889.]

IN the Report of the Wind Force Committee[1] read before the Society in May 1888 the results of some experiments with various anemometers were given, but it was stated that no correction for the natural wind had been applied. Since then a considerable number of further experiments have been made, the total now reaching 103. As previously stated, each experiment consisted of a 15 minutes run of the anemometer in a circle of 58 feet diameter.

Out of these experiments 12 have been made with the friction of the anemometer artificially increased, 7 with a variable velocity, and 14 with the plane of the cups inclined at an angle to the direction of motion. The remaining experiments have been arranged in 5 groups, each group consisting of those experiments in which the velocity was nearest to 5, 15, 25, 35, and 45 miles per hour respectively. Each group has again been split up into two parts, one part consisting of those experiments during which the

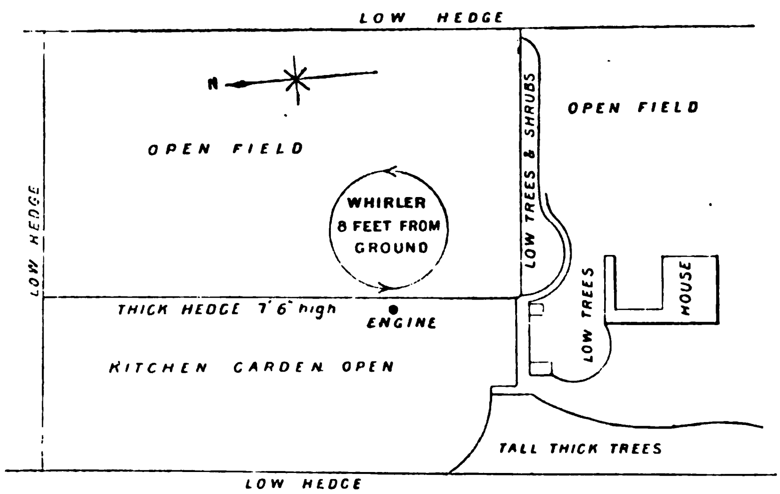



FIG. 1.—Showing the position of the Whirler and its surroundings.

amount of natural wind registered was less than ½ mile, and the other part, of those during which the amount registered exceeded the ½ mile. On many of the days there was not sufficient wind to move any of the anemometers at

[1] *Quarterly Journal*, Vol. XIV. p. 253.

all, and although such days may not have been absolutely calm, it may be taken for granted that the wind velocity was less than 3 miles per hour. With a few exceptions the experiments have been made on calm days, the highest wind velocity ever registered during an experiment being about 8 miles per hour. On account of the uncertainty attending the correction for the natural wind it has been thought better to collect the experiments into groups rather than to treat them separately. It is pretty certain that in the groups headed "Calm," the average velocity has not exceeded 3 miles per hour, for during most of these experiments no wind at all was registered. In the groups headed "Rough," perhaps 6 miles per hour may be taken as the highest possible value for the average. The anemometer employed to measure it, when tested on the whirling machine, was accurate at all velocities exceeding 5 miles per hour, and would begin to turn at a velocity of about 3 miles per hour. Its readings give an average of a little over 4 miles an hour, but since on almost all the days on which experiments were made there were times when no anemometer would move at all, it may be well to take a higher value for the average.

TABLE I.

| Velocity in miles per hour. | Calm. Factor. | Calm. No. of experiments. | Rough. Factor. | Rough. No. of experiments. |
|---|---|---|---|---|
| Between 40 and 50 ... | 2·22 | 6 | 2·12 | 8 |
| ,, 30 ,, 40 ... | 2·19 | 5 | 2·10 | 7 |
| ,, 20 ,, 30 ... | 2·15 | 10 | 2·10 | 14 |
| ,, 10 ,, 20 ... | 2·45 | 5 | 2·09 | 5 |

DETAILS OF EXPERIMENTS.

| Rate in miles per hour. | Factor. | Wind in miles measured during the fifteen minutes. | Direction of wind. |
|---|---|---|---|
| 11 | 1·90 | 1·3 | N |
| 11 | 2·19 | ·5 | NE |
| 11 | 2·20 | 1·1 | N |
| 12 | 2·49 | 0 | E |
| 12 | 2·44 | 0 | E |
| 13 | 2·50 | 0 | E |
| 13 | 2·23 | 0 | W |
| 15 | 2·12 | ·7 | N |
| 16 | 2·37 | ·4 | S |
| 20 | 2·03 | 1.2 | N |
| 20 | 1·83 | 2·1 | NE |
| 20 | 2·11 | ·6 | N |
| 21 | 2·04 | 1·9 | NE |
| 21 | 2·14 | 0 | W |
| 21 | 2·29 | 0 | S |
| 22 | 2·18 | ·7 | NE |

TABLE I.—*Continued.*

DETAILS OF EXPERIMENTS.

| Rate in miles per hour. | Factor. | Wind in miles measured during the fifteen minutes. | Direction of wind. |
|---|---|---|---|
| 23 | 2·05 | 1·0 | NW |
| 24 | 2·16 | ·4 | NE |
| 24 | 2·05 | 0 | S |
| 25 | 2·26 | 1·0 | E |
| 25 | 2·09 | ·9 | N |
| 25 | 2·10 | ·7 | NW |
| 25 | 2·15 | 0 | W |
| 26 | 2·09 | ·3 | NW |
| 27 | 2·13 | 0 | W |
| 28 | 2·04 | 2·0 | NE |
| 28 | 2·08 | ·9 | E |
| 28 | 2·18 | 0 | SW |
| 29 | 2·10 | 1·0 | NW |
| 29 | 2·16 | 0 | W |
| 29 | 2·23 | ·7 | NE |
| 30 | 2·12 | 1·1 | N |
| 30 | 2·13 | 0 | S |
| 30 | 2·13 | ·8 | NE |
| 30 | 2·29 | ·4 | NE |
| 31 | 2·08 | ·8 | N |
| 32 | 2·22 | 0 | W |
| 34 | 2·08 | ·7 | NW |
| 34 | 2·07 | ·9 | NW |
| 35 | 2·10 | ·7 | N |
| 35 | 2·16 | 0 | S |
| 35 | 2·13 | 1·5 (?) | NE |
| 37 | 2·18 | ·7 | N |
| 37 | 2·08 | ·8 | NW |
| 37 | 2·15 | ·4 | NE |
| 37 | 2·29 | 0 | N |
| 38 | 2·14 | ·2 | N |
| 40 | 2·28 | 0 | S |
| 40 | 2·10 | ·7 | N |
| 40 | 2·10 | ·5 | NW |
| 41 | 2·11 | ·7 | N |
| 41 | 2·15 | 0 | SW |
| 44 | 2·10 | 1·2 | W |
| 44 | 2·21 | 1·5 | N |
| 45 | 2·12 | ·8 | W |
| 48 | 2·26 | 1 | NE |

TABLE I.—*Continued.*

DETAILS OF EXPERIMENTS.

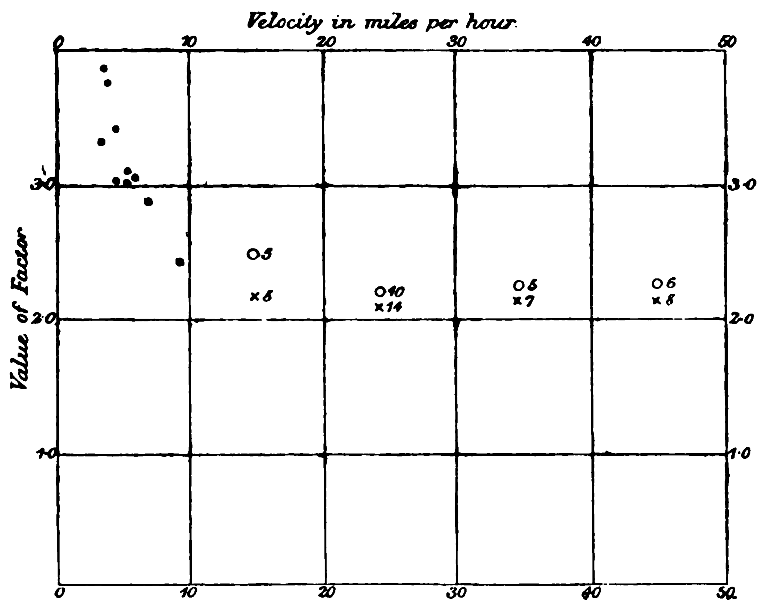
| Rate in miles per hour. | Factor. | Wind in miles measured during the fifteen minutes. | Direction of wind. |
|---|---|---|---|
| 48 | 2·29 | 0 | W |
| 48 | 2·26 | 0 | N |
| 48 | 2·02 | 1.5 (?) | NE |
| 49 | 2·15 | 0 | W |
| 50 | 2·19 | 1·1 | W |

Low speed experiments, all made on calm days :—

| Miles per hour. | Factor. | Miles per hour. | Factor. |
|---|---|---|---|
| 3 | 3·92 | 5 | 3·00 |
| 3 | 3·38 | 5 | 3·09 |
| 3½ | *3·77 | 6 | *3·02 |
| 4 | *3·40 | 7 | 2·89 |
| 4 | 3·01 | 9 | 2·43 |

No wind was registered during any of these low speed experiments, but the three marked thus * were made on a most exceptionally calm day.

FIG. 2.




Kew Pattern Robinson Anemometer.

The low speed experiments are shown separately thus ●
The groups of experiments made on calm days thus ○
Ditto on rough days thus ×
The figures relate to the number of experiments on which each result is based.

In discussing these figures, there are three points which must be taken into consideration; they are, the possibility of the existence of induced eddies (*'Mitwind'*), the effect of the increased friction due to the centrifugal force and gyroscopic action, and the action of the natural wind. The readings of two other anemometers placed on the long arm near the Kew standard throw some light upon these points. The first was a small Robinson anemometer having 1 in. cups on 1·75 in. arms, placed 2 feet nearer the axis of the whirler than the standard. For fear of damage it was not tested at the highest speeds, but unlike the standard it shows a very slight decrease in the value of the factor as the speed increases. It may be of interest to state that the factor of this instrument, deduced from 20 experiments at rates between 10 and 80 miles per hour, is 2·74, and that the experiments made with it are far more consistent among themselves than those made with the Kew standard. It would be affected like the other, but being so much lighter it would take up the proper velocity of rotation more quickly. At one foot from the standard a Helicoid anemometer was placed. The records of this instrument are certainly independent of any friction due to the centrifugal force, since a far greater amount of friction caused artificially had no effect upon it. It has also been tried on the whirling machine, by itself, at speeds up to 70 miles an hour without showing any variation. It will be seen from the tables that the factor of the Kew standard shows a tendency to increase with the velocity on the calm days, rising from its lowest value 2·15, at 25 miles an hour, to 2·22 at 45 miles an hour. Since this increase is hardly noticeable upon the rough days, it is natural to suppose that it may be due to induced eddies, but there is no other evidence in favour of this supposition. The results of the experiments with the small Robinson and the Helicoid anemometer show no sign of it, for it is obvious that it is only on quite calm days that any induced eddies could exist, and these instruments do not show a difference of more than ½ per cent. between the rough and calm days. Also damp vegetation has often been burnt under the whirler to see if any eddy could be detected, but always with a negative result.

The next point to be considered is the effect of the centrifugal force and the gyroscopic action. The experiments, details of which are given in Table II., were made to elucidate this. In the ordinary way the cups would begin to turn with a weight of 40 grains placed in one of them. In these experiments the friction was increased by a brake, and the weight given in the table is the mean of the two weights required just to move the cups at the beginning and end of the experiment.

TABLE II.

| Weight in ounces. | Natural Wind in miles during experiment. | Rate in miles per hour. | Factor. |
|---|---|---|---|
| ½ | ·5 | 39 | 2·15 |
| ½ | ·6 | 41 | 2·17 |
| 3 | ·6 | 45 | 2·38 |
| 3 | ·2 | 24 | 3·62 |
| 3 | 0 | 27 | 4·78 |
| 2 | ·1 | 29 | 2·75 |
| 3 | ·1 | 30 | 2·41 |
| 3 | 6 | 31 | 2·40 |
| 3 | ·1 | 35 | 2·98 |
| 3½ | ·1 | 30 | 3·20 |
| 2 | ·1 | 35 | 2·38 |
| 2 | ·1 | 35 | 2·35 |

The great difference between the figures for the calm and rough days shows that the natural wind is a very important matter. The question of the correction for the wind is complicated by the radial position of the axis of the anemometer. It will be seen at once that in certain parts of the circle the wind direction will not be parallel to the plane of the cups, and the question arises how an anemometer will act under these circumstances. Eight experiments were made with the axis of the anemometer inclined at an angle of 10° to the long arm, and gave 2·31 as the mean value of the factor. Six experiments made with an angle of 37° gave the low mean value of 2·13. However, it is only the former set that are of interest in this connection, for with a wind velocity of 6 miles per hour and a rate of 25 miles per hour for the anemometer, the angle between the plane of the cups and the direction in which the air passes over the anemometer can barely exceed 10° in any part of the circle. The mean value of the factor for the normal position is 2·15, and since the ratio of 2·31 to 2·15 is greater than that of cos 0° to cos 10°, it follows that a little wind blowing during an experiment ought to lessen rather than increase the number of turns of the cups, and thereby increase the value of the factor.

Since the whole question turns upon this point, it may be well to explain it further. In two parts of the circle the wind is blowing across the direction of the anemometer, with the result that it strikes the plane of the cups at a small angle, and also that the relative velocity is increased. The conditions are the same as if the pole on which an anemometer is mounted were inclined towards the wind and at the same time the wind velocity increased. If under these conditions the increased velocity more than compensates for the oblique position of the cups, the registration will be increased, and *vice versâ*. The experiments with the inclined axis show that the influence of the oblique position is predominant when the angle is 10°, and since in

most of the experiments we can see, either by a diagram drawn to scale or by reference to a table of tangents, that the angle must be less than 10°, we are justified in the conclusion, that so far as this point is concerned the natural wind should increase the value of the factor.

Experiments have also been made to determine the extent to which the friction would be altered by the increased pressure on the bearings. At 80 miles an hour the actual pressures are 3 or 4 times as great as when the anemometer is at rest, but it was found that notwithstanding this, when the instrument was weighted in such a way that the actual stresses were made to correspond with those induced by a speed of 80 miles an hour on the whirler, only 60 grains were required instead of 40. This small alteration was quite unexpected, and is probably due to the ball bearings; it shows however that the centrifugal force and gyroscopic action have but a very trifling effect upon these experiments.[1]

Diagrams explaining the action of the natural wind.

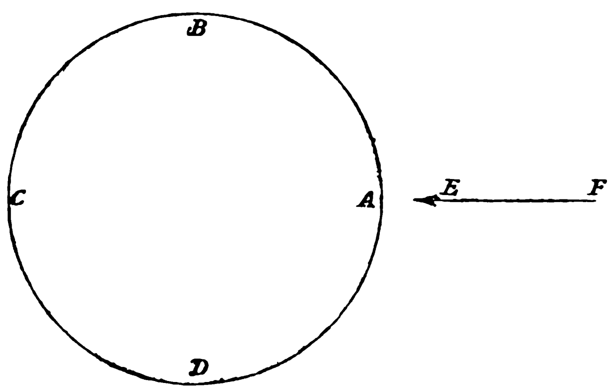



FIG. 3.

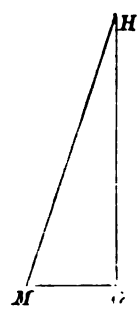



FIG. 4.

In fig. 3 $ABCD$ represents the circle in which the instrument is moving and $FE$ the direction of the wind.

Let $V$ be the velocity of the instrument, and $v$ of the wind.

At $B$ the relative velocity is $V-v$.

At $D$ ,, ,, $V+v$.

At $A$ and $C$ it is $\sqrt{V^2+v^2}$

So far as the parts of the circle at $B$ and $D$ are concerned, the opposite

[1] The forces are a direct outward force $\frac{mv^2}{r}$ parallel to the axis, caused by the centrifugal force; and a couple in a vertical plane due to the gyroscopic action equal to $mk^2w_1w_2$, when $k$ is the radius of gyration, $w_1$ is the angular velocity of the anemometer and $w_2$ of the whirler. Since $w_1=6{\cdot}7w_2$ very nearly, taking 2·15 for the factor, both these forces vary as $v^2$, and the conditions may be reproduced by applying a force $\frac{m\,v^2}{r}$ parallel to the axis of the anemometer and at a distance $\frac{6{\cdot}7\,k^2}{r}$ from it.

effects cancel each other, but the effect is the same at $A$ and $C$, and hence on the whole the mean value of the relative velocity is raised.

Fig. 4 shows the action at $A$ and $C$. $GM$ represents the motion of the wind, $GH$ that of the instrument, and $MH$ the relative motion. If drawn to scale, the air strikes the plane of the cups at an angle equal to $MHG$.

When this angle is 10° the instrument loses from 6 to 7 per cent. on account of its oblique position, but $HM$ is greater than $HG$ by less than 2 per cent., so that there is a loss instead of a gain at the parts of the circle near $A$ and $C$.

On the assumption generally made, the correction for the natural wind is a very small one, excepting at the low velocities; but the figures given in the tables render it clear that, actually, a little more or less wind blowing during an experiment has an important effect upon the result. The way in which the difference between the factors obtained on rough and calm days first decreases and then again increases with the velocity is very curious. The increase seems to be too regular to be due to accidental errors, but, on the other hand, it is very strange that a little wind should make more difference when the speed is 45 miles an hour than when it is only 25 miles. Apart from the possibility of induced eddies I can only suggest one explanation. When the speed is 45 miles an hour the circle is completed in about 3 seconds, and consequently the motion of the air past the anemometer attains its maximum and minimum values at intervals of 1½ seconds. When the speed is 25 miles an hour these maximum and minimum values occur at intervals of nearly 3 seconds.

It may be well to describe here an experiment relating to this subject. Taking the factor as 3, about 5 turns of the cups should correspond to one of the whirling machine, but it is possible to obtain as many as 10 to 12 turns of the cups to each turn of the machine. This is managed as follows:—On a perfectly calm day one complete turn is given to the whirler and it is then allowed to stand still until the cups have nearly come to rest, repeating this process a few times the factor comes out less than 1·5. This shows how much more ready the cups are to take up their proper velocity than to lose it, and it seems probable that many of the discrepancies which have appeared in connection with experiments on this subject are due to this curious behaviour of the Robinson anemometer in a variable wind. The Kew standard pattern is especially liable to this on account of its large "moment of inertia."

Unfortunately it is difficult to obtain a variable speed of short period on the whirling machine when the average speed is at all great. In the 7 experiments which have been made in this way the intervals between the times of maximum and minimum velocity have been from 20 to 30 seconds, and the velocities have ranged from 10 to 40 miles per hour; the mean value of the factor deduced from these is 2·17, that is, about the average, and this shows that when the period of variation is of any length, and the velocity never reaches a very low value, the instrument records a velocity departing but little from the mean value. It must be remembered, however, that at a rate

of 10 miles an hour the factor is considerably above 2·17, so that the result shows that a variable instead of a uniform speed does give a lower factor. There can be but little doubt that the small instrument with the 1 in. cups is much more correct than the Kew standard when the wind is variable, and the greater consistency of the results obtained with it in these experiments is thus explained. There is, however, a reverse side to this, the small instrument is largely dependent upon very little change in the friction, and when placed by the side of another larger instrument in the winter, it was found that its readings were greatly affected by the temperature, presumably on account of the viscosity of the oil. This was so marked, that upon a frosty day its sluggishness was apparent to the eye.

It remains to consider the most probable value of the factor; and it must be confessed at once that the experiments do not show with any certainty the ratio of the wind's velocity to that of the cups for a uniform rate. This perhaps is of little consequence, inasmuch as the instrument is never required in practice to measure a uniform velocity.

For the reasons given above there can be little risk of error in neglecting the correction for induced eddies or for the increased friction caused by the circular motion. It has also been shown that if we assume the instrument to record the mean velocity to which it is exposed, it is almost certain that in virtue of the radial position of the axis, the correction for the natural wind is negative. It is also certain on the above assumption, that for any position of the axis the correction must be very small at all the higher speeds. The formula for this correction is given by Sir G. Stokes in his paper on the Crystal Palace experiments. It is easily obtained by anyone acquainted with the notation of the integral calculus, and its truth is entirely beyond dispute. The conclusion that the instrument is greatly affected by the variability of the wind to which it is exposed seems to be irresistible, and if so, the exact value of the factor must depend upon the nature of the wind as well as upon the mean velocity. There is evidence to show that during a gale the variations of velocity are sometimes of great extent and frequency, and there can be but little doubt that in such a case the factor is less than 2·15. The one point which does seem clear is, that for anemometers of the Kew pattern the value 3 is far too high, and consequently that the registered wind velocities are considerably in excess of the true amount.

Since sending in the Report to the Wind Force Committee, the following series of experiments have been made:—

(1.) The ball bearings of the anemometer were removed and plane bearings substituted. The mean value of the factor, deduced from 7 trials at about 30 miles per hour, was then found to be 2·26; that is an increase of 5 per cent. This is satisfactory, inasmuch as it partially explains the higher value given by the Crystal Palace experiments, especially when it is remembered that the long arm in that case was shorter than the one at Hersham, and therefore the centrifugal force and friction greater.

(2.) Arrangements have been made by which the maximum pressure upon

a foot circular pressure plate could be compared with the maximum speed of rotation of the cups; but, in so far as the determination of the factor is concerned, the plan is a total failure. The maximum pressure always occurs before the cups have taken up their highest speed, and it is not unusual for it to occur in quite a different gust of wind to that in which the cups attain their greatest rate, the rate of the cups depending upon the duration as well as upon the strength of the gust.

The corresponding values are given in Table III.

(3.) Comparisons have been made between the Kew pattern anemometer and a light air meter. The constants of the air meter were carefully determined from time to time upon the whirling machine, and it was exposed by the side of the anemometer about 15 feet above the tower at Woodside, Hersham. The recording dial of the air meter, which was kept facing the wind by a vane, was allowed to remain in action while the centres of the cups travelled over 1,000 feet (corresponding to 79½ revolutions), and thus the distance recorded by the air meter, after correction and cutting off the last three figures as decimals, gave the factor. It was hoped that, choosing so short a distance for each comparison, a fairly uniform speed would be obtained throughout, but such has not been the case. It will be seen that the values (Table IV.) are anything but consistent, but are always far less than the values for the same mean velocity deduced from direct trial on the whirling machine, a result which I believe to be due to the variability of the wind.

TABLE III.

| Maximum pressure in lbs. per square foot. | Maximum rate of revolution of cups in decimals of a complete turn per second. | Factor of anemometer deduced from comparison must be less than |
|---|---|---|
| ·72 | ·60 | 2·78 |
| ·90 | ·66 | 2·84 |
| ·93 | ·71 | 2·66 |
| ·95 | ·75 | 2·55 |
| 1·12 | ·91 | 2·28 |
| 1·75 | 1·08 | 2·41 |
| 1·75 | 1·20 | 2·17 |
| 2·20 | 1·28 | 2·16 |
| 2·45 | 1·44 | 2·13 |

In the above table the maximum rate of the wind was calculated from the maximum pressure, using the experimental result obtained from the same pressure plate, and thus the factor was found which would give the corresponding maximum rate of revolution of the cups.

TABLE IV.

| | Factor. | Approximate mean rate in miles per hour. | | Factor. | Mean rate. |
|---|---|---|---|---|---|
| Nov. 25th, Morng. | 2·15 | 7 | Nov. 26th | 1·87 | 4 |
| | 1·89 | 8 | | 2·72 | 4 |
| | 2·18 | 8 | | 2·20 | 5 |
| | 1·77 | 10 | | 2·41 | 5 |
| | 2·14 | 13 | | 2·72 | 5 |
| | 2·18 | 18 | | 2·30 | 8 |
| | 1·77 | 15 | | | |
| Nov. 25th, Afternoon. | 2·27 | 6 | Nov. 27th | 2·80 | 8 |
| | 2·18 | 7 | | 2·20 | 9 |
| | 2·22 | 7 | | 2·28 | 11 |
| | 2·28 | 8 | | 2·17 | 18 |
| | 2·18 | 8 | | | |
| | 2·47 | 8 | | | |
| | 2·25 | 8 | | | |
| | 2·27 | 10 | | | |
| | 2·24 | 10 | | | |
| | 2·22 | 10 | | | |
| | 2·22 | 12 | | | |
| | 2·22 | 12 | | | |

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## DISCUSSION.

The PRESIDENT (Dr. Marcet) said that Mr. Dines's papers gave evidence of great care and research, and the results were very important: although the exact value of the factor for the Robinson anemometer had not yet been determined, still, an approximation had been obtained which could not fail to be of much value.

Mr. WHIPPLE said that he felt that the investigation could not be in better hands than Mr. Dines's, and he believed that in the matter of the Robinson anemometer all that it was practically possible to do with this instrument had been done.

Mr. BAYARD said that it appeared from the Report of the Committee that all the work done by the Kew pattern Robinson Anemometer was, if not quite worthless, at any rate of a value which was certainly problematic. The smaller anemometers, according to previous experiments, seemed to give much better results, and he would like to know whether the indications of these smaller instruments were of greater value, and whether the observations obtained from them could be utilised.

Mr. SYMONS said that it was unfortunate that anemometry was in such a serious condition as the paper seemed to indicate. His experience with anemometers was very small, but there appeared to him to be no necessity for using

the ponderous cups of the Kew pattern. He had quite recently received an instrument from Richard, of Paris, part of which was an anemometer, consisting of a fan about 18 inches in diameter, very much like an ordinary air meter, but, of course, larger, and more resembling the fan of Whewell's anemometer, and having the blades of the fan made of aluminium, and slightly curved, and the merest touch was sufficient to set the fan spinning.

Captain WILSON-BARKER inquired whether any experiments had been made with other forms of anemometers, as it seemed of little use experimenting further with the Robinson form. He thought the Hagemann form of gauge would give good results.

Mr. MUNRO said that he did not think it was possible to improve the form of the Robinson anemometer; and in the case of the Kew pattern it was not easy to see how the effect of momentum could be overcome. He was satisfied that Mr. Dines's Helicoid anemometer was a better instrument than any other anemometer in existence. He thought that now it was so clearly established that the factor 3 for the Robinson anemometer was wrong, some factor nearer the truth should be used. He believed, from what he had heard, that the fan pattern of anemometer, like that of Richard described by Mr. Symons, was not reliable.

MR. CURTIS said, with reference to the suggested use of small anemometers, that it should be remembered that when anemometers were put up in exposed places, such as Holyhead and other localities on our western coasts, they have to face much greater wind forces than are experienced at an inland station or in a city like London, and therefore they require to be very substantially made. Even with the precautions which are now taken it sometimes happens that an arm is torn away from the rest of the instrument. As to the use of electricity, if an effective system of electrical contacts could be arranged it would doubtless be a great advantage, because by its use difficulties due to the necessity which now exists for placing the instrument on buildings—always more or less unsuitable—could then be avoided, and something like uniformity could be secured in the conditions of exposure. But the great obstacle to its use lay in the difficulty involved in keeping the contacts, necessarily exposed to the weather, in good working order; and some recent experience of this at Valencia had shown that the difficulty was exceedingly great. At the same time, a comparison which had been made there between two similar instruments working side by side, but the one recording in the ordinary way and the other by means of an electrical arrangement, had shown a very close agreement between the records of the two. With reference to the effect of variation in the wind-force upon the speed of the cups, he had found, from some experiments he had himself carried out, that the Robinson cups took up any increase in the speed of the air passing over them very readily, and he had supposed that, when the wind fell again, they parted with their motion as speedily; but Mr. Dines's experiments seemed to show that such was not the case. The variations in the force of the wind in short intervals of time (as shown in enlargements of records from Osler's anemometer exhibited to the Meeting) were sometimes extremely great. The indications of the "bridled" anemometer at Holyhead also showed this feature remarkably well. During a gale in October 1889 the record from this instrument showed several remarkable oscillations of this character, and in one instance the pencil was driven considerably beyond the scale on the occasion of a strong gust of wind. These gusts appeared to be regular in their recurrence, and to come in groups, with a tolerably uniform interval of time between them; indeed, there appeared to be two distinct sets of gusts, the one occurring when the general strength of the wind was comparatively low, and the other when its average strength was much greater, as if there was a regular pulsation or set of waves in the air, with a distinct set of sudden oscillation occurring both with the trough and the crest of the waves. As the gale died out, these pulsations became less distinct, and gradually died out.

Mr. SCOTT asked if the fan instruments used in the Metropolitan Railway Tunnels, referred to by Mr. Munro, had been really Whewell's Anemometers, or Airmeters like those sold at present. Dr. Whewell described his anemometer as a kind of small windmill with 8 sails inclined at an angle of 45° to the wind and kept facing the wind by a vane. The registering apparatus was an essential part of this instrument.

Mr. MUNRO remarked that the Kew-pattern anemometer used by Mr. Dines

in these experiments was slightly heavier (perhaps one pound) than the instrument at Kew. The great difficulty in constructing the cup anemometer has been to make it of sufficient strength to stand the hard wear and tear which it is subject to.

Mr. LAUGHTON thought that Mr. Dines's observations dealt a death-blow to the Robinson's anemometer. He had long felt a distrust of the instrument, and had said, many years ago, that the first and most pressing need of anemometry was a new type of head. It was satisfactory to find this opinion so fully confirmed by the results of Mr. Dines's experiments. He entirely agreed with Mr. Whipple, that little good was to be expected from further experiments with Robinson's cups; but he earnestly hoped that now, or at some later period, Mr. Dines would be able to carry on some investigations with other forms of anemometers, and more especially with his own Helicoid and the Hagemann pipe, both of which seem full of promise, when once we are lifted clear of the rut which has so long confined our footsteps.

Prof. A. S. HERSCHEL said that Mr. Dines having recently shown him in actual progress his process of proving anemometers, and of measuring wind-pressure coefficients on his large steam whirling-crane at Hersham, enabling him to note the perfect working action of its self-adjusting and recording mechanisms, and making him familiar with his many happy inventions of practical improvements in wind and weather recording instruments, he wished to say a few words on what he regarded as some points of great value in the papers. He would desire in the first place to notice especially the conspicuous ingenuity with which the experiments described had been conducted, and the mathematical resource and skill with which, in deducing the results, the probable sources of error were discussed and sought to be allowed for, or eliminated, as being such, he thought, as must command great confidence in the inferences and conclusions drawn by the Wind Force Committee from the long and carefully pursued series of experiments which had been recorded. From these it appeared to be now quite certain, that the Robinson form of anemometer is not such a direct and simple indicator of the wind's velocity as it has hitherto been generally supposed to be. On the other hand, the ratio of the wind's speed to that of the cups, if not actually constant, yet only shows small changes, as if some modification could perhaps be found which would render it more stable; and it is very decidedly shown to be more nearly 2 : 1 than 3 : 1, which was the value used, and thenceforth adopted, in the theory of the instrument first proposed by its inventor. As a prominent example of the great inventive skill employed in these experiments, their complete establishment of the exactitude of Hutton's law of wind pressure, that for a given obstructing surface (without any limitations apparently of the outline, or solid figure), the pressure of a blast varies as the square of the wind's velocity, shown to be strictly true for a pretty considerable range of velocities, by balancing the centrifugal action of a small lever's weight against that fluid pressure at the circulating arm-end of the whirling-crane, was a result of the inquiry upon which, by itself alone, the Society might be felicitated which had subsidised these experiments, and which had now quite recently published in its *Quarterly Journal* this very significant outcome, with many most important variations on it, of the investigation. If then this law may be trusted strictly in the case at least of a flat pressure-board, we may perhaps hopefully expect that the form of anemometer introduced by Mr. Follett Osler, recording wind-currents by their pressures, of some of whose registrations Mr. Dines had shown them an interesting diagram to illustrate his paper, will in the end prove practically to be the most trustworthy form of wind-recording instrument; and he would like to ask Mr. Dines if they might not now consider that the pressure of a wind upon the flat square pressure-plate of Osler's anemometer may be regarded as always exactly proportional to the square of the wind's velocity?

In connection with the reading of the second paper, an instrument was referred to which was shown upon the table, for indicating directly the velocity of a fluid current by first making the current produce its natural fluid pressure. The new instrument had not, he thought, been dilated on at sufficient length by Mr. Dines for its very perfect action to be made known to the meeting as fully and distinctly as the ingenuity of its construction merited. Prof. Herschel however hoped that he would not be disclosing more of this instrument's most elegant contrivance than Mr. Dines himself was anxious to divulge at present, if he tried to explain to the

Society a little more fully than Mr. Dines had been content to do, the beautiful simplicity and the remarkable ingenuity of its construction.

The head of pressure due to air velocity can either be shown directly by a Lind's wind-gauge in inches of water-column supported in the straight limbs of the bent water-tube, when the wind-current blows directly into the open mouth of the gauge-tube, or else, if the current gives rotation to a Robinson's, or Lownes' anemometer, this will make water or mercury contained in a cup revolving on the axle of the anemometer rise at the circumference of the cup, and measure the same pressure by its change of level. A centrifugal pump, elevating the liquid from one large trough or cistern to another, takes the place in this case of the simple bent water-tube of Lind's wind-gauge. To translate this elevation into its corresponding wind-velocity requires a calculation by the rule that it bears a constant ratio to the square of that velocity. If now a pendulum-bob floats on the lifted fluid surface in the trough, like a cork buoy, the pendulum-stem being vertical when there is no elevation, or when no pressure and speed are being indicated, and if the stem's upper end is socketed in this position so that the pendulum can turn round it without rising, an elevation of the liquid in the trough makes the pendulum to slope outwards, and its point to depart from its lowest vertical position to a horizontal distance from it, whose square is, by a simple geometrical property of a circle, proportional to the rise in height for all movements of the bob which are small in their extent compared with the pendulum-stem's length.

The problem of effecting this change of measurement from one equivalent way of expressing an air-current's rapidity or force of stream to the other, by some commodious mechanical means exact enough to be for all ordinary purposes a substitute for calculation, had some time ago been suggested to Prof. Herschel as a great *desideratum* by Mr. G. M. Capell, and he had partially succeeded with a square-cornered triangle on a drawing-board in meeting the requirements. But the present ingenious use of the lateral displacement of a floating pendulum in a circle had, when shown to him by Mr. Dines, quite surprised him by its perfect simplicity and fitness. In the neat state exhibited of its now finished adaptation to a revolving anemometer, he felt sure that its inventor and the skilful constructor of the instrument had succeeded together in producing a kind of actual indicator of varying velocity, which would hereafter, without doubt, prove to be of the greatest service in the study of anemometry.

Mr. W. H. DINES, in reply, said that he had only gone into the question of the factor of the Kew Standard anemometer, and therefore could not say much about the smaller kinds; but he believed that all sizes were more or less dependent upon the character of the wind. He would not go so far as to say that the factor might in some instances be double what it was in others, but he thought that there was still an uncertainty about it to the amount of 30 per cent. Mr. Curtis had remarked that the cups took up the velocity very quickly. No doubt they did so, but unfortunately they did not lose it with equal quickness, and it was this that made the instrument so unreliable. He had tried a good many anemometers, both of the Robinson and of the air-meter type, and also his own Helicoid anemometer. With regard to the latter, as the results were given in the preceding report, he would say nothing further about it. He had found that, having once tested an air meter, it was possible to predict the result of a second trial to within one or, at most, two per cent., and hence he considered the air-meter type of anemometer to be the best. He agreed with Professor Herschel that since the pressure varied as the square of the velocity, the velocity could always be found when the pressure was known. He liked the Robinson anemometer on account of its simplicity; but he thought no instrument of that type could be depended upon to give the real mean velocity, because there was no doubt but that they all took up the proper velocity more quickly than they lost it. No modification of the factor could remedy this, because the departure from the mean was greater for a gusty than for a comparatively steady wind. This conclusion was the same as that which had been deduced from the American experiments, but it had been reached quite independently. He certainly thought that the factor 3 should be altered, or at least that the wording of the Kew certificate—viz. "of the true amount"—should be changed, for it seemed to him absurd to continue calling the records of the Kew Standard "the true amount" when everyone acquainted with the matter knew well that they were nothing of the kind.

# ON TESTING ANEMOMETERS.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received October 18th—Read December 18th, 1889.]

THERE are, theoretically, two plans on which an anemometer may be tested, and the constants of the instrument determined, but both present considerable practical difficulties. The first is to make a current of air pass over the instrument at a known velocity; but since there is no perfectly correct method of measuring the velocity, the only way is to place the instrument in a tube and make a given volume of air, for example, the contents of a gasholder, pass through the tube in a given time. This plan, however, is not satisfactory, for the air undoubtedly moves faster at the centre than at the sides of the tube, where it is impeded by skin friction, and also, unless a tube of very large cross section were employed, the instrument would occupy an appreciable portion of the space, and the calculation of the velocity would be rendered almost impossible.

The second plan is to move the instrument itself at a known rate through still air, and if only still air could be obtained, there would be no further difficulty. A little consideration shows that it cannot matter whether the air pass over the instrument, or the instrument itself be moved through the air. In either case we obtain the velocity of the air relatively to the instrument, and nothing more. In the first the instrument is only fixed relatively to the earth's surface, and if it were possible to suppose a difference between the two cases, it would be necessary to go still further, and say that the motion of the earth itself must affect the result.

In consequence of the expense which would be incurred by arrangements suitable for moving an anemometer in a straight line, almost all experiments on the subject have been made with circular motion. Provided that the radius of the circle be large compared with the size of the instrument, the circular motion itself is perhaps unobjectionable; but, unfortunately, two difficulties are introduced by it. The force required to retain the instrument in its circular path being very considerable, special care is necessary in the mounting, and after every precaution has been taken, the pressure of the moving parts of the instrument on the bearings, and therefore the friction is undoubtedly greater than it would otherwise be. This must alter the result, although the extent to which it does so is probably slight.

The second difficulty is that the instrument is constantly moving over the same spot at short intervals of time, and consequently some of its motion is imparted to the air, which soon ceases to be perfectly still. This is particularly the case if the experiments are conducted in a closed building, and if the instrument is of any size or the speed at all great, the eddy set up

is very considerable. This second trouble is almost avoided by working in the open air, but it is, unfortunately, replaced by another. It is very seldom indeed that it is absolutely calm, and possibly during such a calm the same sort of eddy that occurs indoors might be set up by a large instrument, such as the Kew pattern anemometer, moving at a high speed. For certain kinds of instruments, however, the natural wind does not matter so much, but the difficulty of knowing how to allow for it in the case of the Robinson anemometer is very great. There are three reasons for this. In the first case the wind never blows uniformly, and any correction based on the assumption that the wind is steady is not correct; secondly, if the anemometer does not register the same percentage for different velocities a further difficulty is introduced; but perhaps this need not be considered, unless the rate of the natural wind be nearly equal to that of the instrument. The other difficulty seems to belong especially to the Robinson anemometer. If this instrument be exposed to a wind, the velocity of which varies within wide limits at short intervals of time, it records a higher rate than it would do if exposed to a steady wind of the same mean velocity. The instrument, when in actual use, is exposed to a variable velocity, so that there is a certain advantage in trying experiments under circumstances which do, to some extent, agree with the actual conditions.

Suppose an anemometer to be moved in a circle at a rate of 40 miles an hour, and that the wind is blowing at 8 miles an hour, it is clear that the relative rate of the anemometer ranges from 32 to 48 miles an hour, it being 32 in the part of the circle in which it is moving with the wind and 48 in the opposite part. Also it may be shown that the mean relative velocity is very nearly equal to $40\frac{2}{5}$ miles per hour. An ordinary wind, the mean velocity of which is about 40 miles per hour, probably varies between far greater limits; but at present we know little about the extent or frequency of the variations, so that when we have found the constants of the Robinson anemometer for a uniform speed we shall still be uncertain about the results when the speed is variable. Still, a wind varying between the limits of 32 to 48 miles per hour is no doubt nearer to what occurs in practice than a perfectly uniform rate of 40 miles per hour would be.

If we make three assumptions, there is no difficulty in finding the corrections which should be applied in the case of experiments made in the open air while there is some natural wind. Suppose that $u$ is the rate of the instrument, and $v$ that of the wind; also assume (1) that the wind is blowing steadily; (2) that the registration of the instrument is practically uniform for all rates lying between $u+v$ and $u-v$; and (3) that the instrument records the mean velocity to which it is exposed. Then if $\frac{v}{u}$ is so small that $\left(\frac{v}{u}\right)^4$ and higher powers may be neglected, the velocity recorded by the anemometer should be $u+\frac{1}{4}\left(\frac{v}{u}\right)^2 u$. In the hypothetical case given above—namely, $u = 40$ and $v = 8$—this gives a correction of only 1 per

cent., so that if the three assumptions made above were allowable, a slight or even moderate breeze blowing during the experiment would not be of much consequence.

There is one other point which should be considered. A Robinson anemometer is always placed with its axis vertical, and when in that position its record of the velocity is quite independent of the direction of the wind. When experiments are made with a whirling machine, and the axis of the instrument is vertical—that is, parallel to the axis of the whirler—the inner cup has a much smaller velocity than the outer, and consequently experiments so made, and taken alone, are not of the least value. It is usual to reverse the position of the cups, so that they shall turn in the opposite direction, and then make another set of experiments. Using the number of turns of the cups relatively to the whirler—that is, the sum of the numbers of turns of both, when both turn in the same direction, and the difference when they turn in opposite directions, and taking the mean of the two sets—the final result must be very nearly correct. The trouble of making a double set of experiments may, however, be avoided by placing the axis parallel to the long arm of the whirler. In this position, assuming that the air is still, the direction of motion is parallel to the plane of the cups; and although in practice an anemometer is never placed in this position, yet, when experimenting with a whirling machine, it represents the actual conditions more nearly than the vertical position would do. So long as the plane of the cups is parallel to the direction of the wind, it cannot matter in what particular position the instrument is placed, the only possible effect being a slight alteration of the friction. But in testing an anemometer upon a whirling machine, any slight alteration in the friction which may occur on account of the radial position of the axis is very trifling when compared with the alteration which is inevitably produced by the effect of the centrifugal force.

# ON THE RAINFALL OF THE RIVIERA.

By G. J. SYMONS, F.R.S., Secretary.

(Plates II.-IV.)

[Received September 13th.—Read December 18th, 1889.]

REQUIRING information respecting the rainfall of one of the towns on the Mediterranean coast of the Department of Alpes Maritimes, I was very much surprised to find how little was said about it even in the best books upon Cannes, Mentone, Nice, and the other towns on that lovely coast.

I was, therefore, obliged to collect what I could, and having done so it occurred to me that this collected material should be rendered generally accessible. This is the more desirable because Lord Brougham and Vaux has been kind enough to send me a complete copy of the very important and unbroken record kept at his Villa from 1865 to the end of 1888, and which has hitherto been unpublished. Besides it, I have collected observations from various sources, especially from the volumes *Pluies en France*, published by the French Meteorological Office, and from Professor Raulin's *Observations Pluviométriques*.

In order to utilise the records which are themselves too short to afford trustworthy means, it has been necessary to choose some standard stations, and there are four at each of which the record is perfect for the ten years 1877 to 1886. The totals at each of these stations have been converted into their ratios to the mean of the ten years, and the average ratio for each year has been assumed to represent the percentage by which each individual year was wetter or drier than the ten year mean. These values are given in Table I., and they are also plotted on Plate II., in order to show by their close general accordance how safe is this mode of calculation.

In Tables II. to X. is given the monthly and annual fall at every station whence I could procure it, and those values, uncorrected when they embrace at least ten years, and corrected by the ratios in Table I. where they are for less than ten years, give the following approximate averages:—

APPROXIMATE MEAN ANNUAL RAINFALL AT STATIONS ON THE RIVIERA.

| | | | | | Inches. |
|---|---|---|---|---|---|
| Cannes— | Villa Louise Eléonore, | 1865 to 1888, | 24 years... | ... | 31·89 |
| ,, | ,, ,, ,, | 1877 to 1886, | 10 years... | ... | 30·59 |
| ,, | ? ,, ,, | 1877, | 1 year ... | ... | 24·6 |
| ,, | Ponts et Chaussées, | 1880 to 1886, | 7 years... | ... | 30·6 |
| ,, | M. Reynaud, | 1883 & 1884, | 2 years... | ... | 30·0 |

### Approximate Mean Annual Rainfall at Stations on the Riviera.

*Continued.*

| | | | Inches. |
|---|---|---|---|
| Antibes—La Garouppe (Lighth.) | 1877 to 1886, 10 years... | ... | 28·67 |
| Nice—École Normale, | 1877 to 1886, 10 years... | ... | 31·22 |
| ,, Port, | 1880, 1 year ... | ... | 29·0 |
| ,, Observatory (1116 ft.), | 1883 to 1886, 4 years... | ... | 26·7 |
| Villefranche (Lighthouse), | 1877 to 1886, 10 years... | ... | 27·52 |
| Monaco, | 1880 & 1881, 2 years... | ... | 22·3 |

Besides the above, I have found incomplete records and several mean values which afford the following results:—

| | | | Inches. |
|---|---|---|---|
| Nice (quoted by Smollett), | 1849 to 1878, 30 years .. | ... | 32.2 |
| ,, (quoted by Roubadi), | ... | ... | 25·8 |
| ,, (quoted by Raulin), | 1829-31 & 1838-42 imp. ... | ... | 29·6 |
| ,, ( ,, ,, ,, ), | 1870 to 1874, 5 years... | ... | 35·2 |
| ,, Military Hospital, | 1864 to 1873 imp. ... | ... | 36.3 |
| ,, École Normale, | 1865 to 1874 imp. ... | ... | 32·8 |

Mentone—Various values ranging from 28·7 to 32·0.

The positions of these several towns are shown on the sketch map, Plate III.

The values given above differ so greatly for the same town as to leave one in doubt which to accept, but the impression left upon my mind is that the total annual fall along the Riviera from Cannes to San Remo is about 31 inches, and that any difference between the several towns has yet to be proved. The maps of Keith Johnston, of Krümmel, and of Angot all show a rainfall increasing from West to East. This may be true inland, but there is certainly no distinct evidence of it in any observations on the coast.

*Monthly Fall.*

The information upon this subject is very accordant. There is usually about 2 inches a month up to and including May, then there are three dry summer months—June, July, and August—followed by three with large totals (4 inches or 5 inches each), and then December drops to about the average of the early months of the year.

These details will be better grasped by reference to Plate IV.

There is, however, an anomaly with respect to the fifth curve, that representing the observations from Nice for 1849-78, viz. that though the shape of the curve is very similar to the other four, all the features occur a month earlier. I have not the original, and cannot therefore say whether it is true, or due to an error in copying. Each seems to be equally improbable.

*Rainy Days.*

Days with less than 0·04 inch are, I think, rarely recorded in that district, and, with the generally bright sun and dry air, such falls would be of little importance. Still, when we find that the total of days of rain on the Riviera

is about 65 per annum instead of from twice to three times that number, as recorded in England, we may perhaps derive some comfort from remembering that if a British observer were to reside there he would probably pick up sundry little showers which now escape notice. He might perhaps turn the 65 into 75, but even if so the total remains very small.

*Heavy Falls.*

Evidently with more rain than London, and less than half as many days with rain, the falls individually must be greater, and so they are; in London falls of three inches in 24 hours are very scarce, but not so on the Riviera—there it either rains heavily, or it is fine. If it rains, the probability is that there will be half an inch before it is over—and as far as I can judge, it seems that the characteristics of the heavy falls on that coast are, *not* such short and intense rains as we get during thunderstorms in England, but persistent heavy rains, say 0·5 in. per hour for 8, 10, or 12 successive hours—that was the character of one of the great rains of the decade 1877-86, viz. that of October 26th, 1886, when I happened to be at Cannes and able to watch it. That day of the year (by-the-bye it is very near the anniversary of our Royal Charter storm) is frequently very wet. The late Lord Brougham informed me that at his Villa on October 27th, 1882, the fall between 2.30 p.m. and midnight was 4·50 inches, or half an inch an hour for 9½ successive hours. In the same letter his Lordship said that he had once measured "an inch in twenty minutes." That was certainly an exceptional fall, but much more remarkable cases are on record during the last 10 years in the British Isles, the greatest being 1·78 in. in 20 minutes during the great thunderstorm of June 23rd, 1878, at Camden Square.

I ought perhaps to apologise for the sketchy nature of this paper, but if nothing is to be done unless it can be done perfectly, very little will be done. And no one will be more pleased than I shall be, if this paper is shortly superseded by a better one.

P.S.—There was one other record of which I knew when writing the foregoing paper, but of which I could say nothing, because I had not the values. I refer to the record kept from 1866 to the present time by the talented author of *Cannes et son Climat* and other works, Dr. De Valcourt. He has been so good as to prepare a table of the monthly and annual rainfall, and the number of days, which I hope that the Council will allow me to add to my paper, as greatly increasing its value. The mean rainfall agrees closely with that reported by Lord Brougham, viz. 31 inches, and the average number of days with rain is 70, thus agreeing closely with the other stations, which give about 65. The wettest year was 1872, 66·09 inches, the driest 1877, 17·38 inches. The wettest month, October 1872, with 20·59 inches, and the wettest day, October 27th, 1882, 5·48 ins. in 8 hours; this being the day on which Lord Brougham recorded 4·50 ins.

## TABLE I.

Ratios of each Year 1877-1886 to the Mean of the whole period.

| Year. | Cannes. Villa Louise Eléonore. | Antibes. La Garouppe. | Nice. École Normale. | Villefranche. | Adopted Mean. |
|---|---|---|---|---|---|
| 1877 | 67 | 87 | 88 | 107 | 87 |
| 1878 | 75 | 92 | 106 | 117 | 98 |
| 1879 | 145 | 136 | 116 | 124 | 130 |
| 1880 | 86 | 78 | 81 | 80 | 81 |
| 1881 | 115 | 112 | 102 | 112 | 110 |
| 1882 | 103 | 94 | 115 | 98 | 103 |
| 1883 | 122 | 103 | 107 | 100 | 108 |
| 1884 | 67 | 60 | 65 | 49 | 60 |
| 1885 | 106 | 112 | 113 | 101 | 108 |
| 1886 | 114 | 126 | 107 | 112 | 115 |
| Mean .. | 100 | 100 | 100 | 100 | 100 |

## TABLE II.—Rainfall at Cannes (Villa Louise Eléonore.)

| Year. | 1865. | 1866. | 1867. | 1868. | 1869. | 1870. | 1871. | 1872. | 1873. | 1874. | 1875. | 1876. | 1877. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January | 1·48 | ·09 | 7·84 | 1·48 | 1·09 | 1·21 | 2·21 | 6·19 | ·78 | 1·90 | ·12 | .98 | 1·98 |
| Feb. .. | 1·40 | 1·75 | 4·14 | ·58 | 1·11 | 5·55 | 1·42 | 2·31 | 2·68 | 3·88 | ·55 | ·00 | ·00 |
| March | ·23 | 8·15 | 4·40 | 3·79 | 4·00 | 2·13 | ·76 | 6·19 | 4·45 | 1·37 | ·12 | 3·00 | 3·68 |
| April .. | 2·15 | 4·43 | ·66 | 1·32 | ·66 | ·92 | ·70 | 4·00 | 3·72 | 3·87 | 3·53 | 3·87 | 2·98 |
| May .. | ·70 | 2·85 | 1·52 | ·22 | 2·71 | ·00 | 4·44 | 3·04 | 2·52 | ·35 | ·53 | 1·42 | 3·04 |
| June .. | ·27 | ·31 | ·00 | ·11 | ·92 | 2·18 | 2·59 | ·00 | ·39 | 1·18 | 4·51 | ·95 | ·45 |
| July .. | 1·09 | ·53 | ·08 | ·70 | ·00 | ·82 | ·00 | 2·50 | ·00 | ·27 | ·45 | ·06 | ·24 |
| August | 1·39 | 1·09 | 1·16 | ·44 | ·20 | 3·84 | ·00 | ·00 | ·00 | .00 | 1·20 | 1·38 | ·07 |
| Sept. .. | ·15 | 3·71 | ·47 | 8·06 | 2·06 | ·00 | 4·72 | ·23 | ·65 | 2·71 | ·56 | ·12 | ·09 |
| October | 11·50 | 7·23 | 2·90 | 7·52 | 1·19 | 2·83 | ·36 | 16·90 | 8·11 | 4·44 | 4·97 | 4·02 | 2·82 |
| Nov. .. | 4·23 | ·06 | 2·00 | 5·87 | 7·30 | 8·51 | 10·28 | 4·13 | 7·95 | ·50 | ·30 | 5·48 | 5·07 |
| Dec. .. | 5·58 | 1·65 | 4·23 | 2·09 | 3·49 | ·44 | 6·10 | 13·91 | ·00 | 2·92 | 1·76 | 5·96 | ·16 |
| Totals | 30·17 | 31·85 | 29·40 | 32·18 | 24·73 | 28·43 | 33·58 | 59·40 | 31·25 | 23·39 | 18·60 | 27·24 | 20·58 |
| Max. fall | 2·95 | 6·20 | 2·50 | 2·16 | 7·30 | 3·88 | 5·00 | 3·90 | 2·92 | 2·45 | 3·60 | 2·40 | 2·60 |
| Days of rain | 63 | 58 | 54 | 61 | 39 | 37 | 50 | 62 | 43 | 32 | 32 | 43 | 29 |

| Year. | 1878. | 1879. | 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. | 1888. | Mean 24 yrs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January .. | ·00 | 4·76 | ·35 | 5·42 | 2·19 | 10·42 | ·91 | 4·31 | 5·45 | 4·72 | 1·02 | 2·79 |
| February .. | ·00 | 3·58 | 3·28 | 2·98 | 1·03 | 3·32 | 1·09 | 5·45 | 2·38 | 1·28 | 2·58 | 2·18 |
| March .. | 1·34 | 7·79 | ·12 | 1·00 | 1·65 | 6·40 | 1·27 | ·97 | 2·08 | ·88 | 6·88 | 3·03 |
| April .. | 2·45 | 8·71 | 2·26 | 1·38 | ·94 | 5·31 | 3·77 | 2·75 | 3·42 | 4·12 | 1·94 | 2·91 |
| May .. .. | 1·26 | 6·96 | 2·99 | 4·03 | 3·19 | 2·19 | 1·51 | 1·13 | 1·20 | ·49 | ·16 | 2·02 |
| June .. .. | 1·71 | ·32 | 3·04 | ·64 | ·00 | ·94 | 2·91 | 4·35 | ·66 | 1·85 | 2·22 | 1·35 |
| July .. .. | ·00 | ·34 | ·00 | ·00 | ·15 | ·52 | ·14 | ·00 | ·10 | 1·01 | ·43 | ·39 |
| August .. .. | 1·60 | ·40 | 2·88 | 3·18 | ·10 | ·12 | ·16 | 1·01 | 2·10 | ·15 | 3·38 | 1·08 |
| September .. | ·98 | 6·87 | 2·27 | 4·00 | 6·25 | 3·10 | 1·90 | 1·10 | 1·62 | ·79 | 1·60 | 2·25 |
| October .. | 3·06 | ·63 | ·66 | 5·85 | 12·34 | 2·39 | 2·32 | 6·30 | 7·91 | 4·08 | ·85 | 5·05 |
| November .. | 6·71 | 3·22 | 8·18 | 3·59 | 1·00 | 1·90 | ·40 | 4·41 | 6·41 | 12·56 | 15·27 | 5·22 |
| December .. | 3·91 | ·62 | ·20 | 3·15 | 2·72 | ·77 | 4·13 | ·56 | 1·56 | 3·87 | 17·08 | 3·62 |
| Totals .. .. | 23·02 | 44·20 | 26·23 | 35·22 | 31·56 | 37·38 | 20·51 | 32·34 | 34·89 | 35·80 | 53·41 | 31·89 |
| Max. fall .. | 1·60 | 3·10 | 3·40 | 3·10 | 4·70 | 3·20 | 2·00 | 3·60 | 3·00 | 3·05 | | 5·80 |
| Days of rain | 49 | 59 | 43 | 60 | 42 | 53 | 44 | 50 | 61 | 49 | | 51 |

| Year. | III. Cannes. Above Sea 10 ft. | IV. Cannes (Ponts et Chaussées). Above Sea 16 ft. | | | | | | | V. Cannes (Reynaud). Above Sea 49 ft. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1877. | 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | 1883. | 1884. | 1885. |
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January .... | 1·50 | ·35 | 5·59 | 1·22 | 7·76 | ·59 | 2·64 | 4·88 | 4·57 | ·79 | 2·13 |
| February .... | ·04 | 3·03 | 2·05 | 1·10 | 3·42 | 1·10 | 4·13 | 2·56 | 5·55 | ·67 | 3·78 |
| March ...... | 3·98 | ·16 | ·52 | 1·54 | 7·28 | 1·81 | 1·14 | 1·81 | 6·02 | 1·89 | ·59 |
| April ........ | 2·76 | 3·98 | 1·57 | 1·06 | 4·45 | 3·58 | 3·31 | 1·18 | 4·02 | 3·19 | 2·60 |
| May ........ | 3·50 | 1·89 | 4·10 | 2·13 | 1·93 | 1·85 | 1·34 | 1·57 | 1·89 | 1·77 | 1·50 |
| June ........ | ·63 | 1·97 | ·59 | ·00 | 1·22 | 2·72 | 5·39 | ·91 | ·98 | 2·76 | 4·88 |
| July ........ | ·32 | ·00 | ·00 | ·39 | ·71 | ·16 | ·00 | ·28 | ·71 | ·16 | ·00 |
| August ...... | ·08 | 2·52 | 3·70 | ·16 | ·16 | ·12 | 1·77 | 1·73 | ·16 | ·08 | .. |
| September .. | ·12 | 3·15 | 1·85 | 4·21 | 3·74 | 2·01 | 2·32 | 1·46 | 3·15 | 1·34 | .. |
| October ...... | 1·38 | 1·22 | 5·91 | 11·06 | 2·36 | 2·40 | 8·07 | 9·65 | 2·01 | 2·40 | 8·94 |
| November .. | 6·81 | 6·02 | 3·66 | ·71 | 1·77 | ·39 | 4·06 | 6·22 | 1·89 | ·39 | 3·47 |
| December .... | ·28 | 1·69 | 2·64 | 2·44 | ·71 | 3·66 | ·71 | 2·48 | ·63 | 3·31 | ·39 |
| Totals ..... | 21·40 | 25·98 | 32·18 | 26·02 | 35·51 | 20·39 | 34·88 | 34·73 | 31·58 | 18·75 | .. |
| Max. Fall...... | 2·32 | 2·72 | 2·05 | 5·47 | 2·52 | 1·89 | 3·94 | 2·28 | | | |
| Days of Rain .. | | | | 56 | 70 | 58 | | 74 | 69 | | |

VI.—Antibes (La Garouppe). Above Sea 266 feet.

| Year. | 1877. | 1878. | 1879. | 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January.... | 1·81 | ·55 | 3·62 | ·28 | 6·54 | 2·99 | 4·61 | ·67 | 3·11 | 4·33 | 2·85 |
| February .. | ·00 | ·04 | 5·35 | 4·10 | 1·06 | ·63 | 4·57 | ·79 | 3·66 | 2·13 | 2·23 |
| March .... | 4·72 | 1·06 | 4·45 | ·08 | 1·14 | ·98 | 5·12 | 1·85 | ·71 | 1·73 | 2·18 |
| April ...... | 2·44 | 2·79 | 6·42 | 1·89 | 1·18 | ·32 | 3·82 | 3·11 | 1·97 | 2·40 | 2·63 |
| May ...... | 3·07 | 1·26 | 6·06 | 1·81 | 5·39 | 1·50 | 1·58 | 1·46 | .94 | 1·77 | 2·49 |
| June ...... | ·24 | 1·34 | ·16 | 1·58 | .71 | ·00 | 1·18 | 1·50 | 6·65 | 1·10 | 1·43 |
| July ...... | ·55 | 1·18 | ·24 | ·00 | ·00 | ·28 | ·43 | ·00 | .16 | ·08 | ·29 |
| August .... | ·00 | 1·06 | ·32 | 1·89 | 3·15 | ·04 | ·35 | ·28 | ·55 | 1·38 | ·90 |
| September | ·51 | 1·85 | 7·91 | 3·03 | 5·16 | 5·75 | 4·25 | 2·20 | 5·00 | ·94 | 3·66 |
| October .... | 4·02 | 4·17 | ·83 | 1·50 | 3·70 | 10·98 | 1·69 | 2·21 | 4·68 | 9·61 | 4·34 |
| November .. | 7·36 | 7·48 | 1·50 | 5·20 | 2·95 | ·79 | (1·38) | ·67 | 4·21 | 7·80 | 3·93 |
| December .. | ·35 | 3·50 | 2·05 | 1·02 | 1·26 | 2·56 | ·59 | 2·60 | ·35 | 2·87 | 1·72 |
| Totals .... | 25·07 | 26·28 | 38·91 | 22·38 | 32·24 | 26·82 | (29·57) | 17·34 | 31·99 | 36·14 | 28·67 |
| Max. Fall.... | 3·62 | 1·18 | 3·50 | 2·20 | 3·19 | 5·00 | 1·61 | | | 5·00 | |
| Days of Rain | | | | | | 52 | .. | 54 | | 61 | .. |

VII.—NICE. ÉCOLE NORMALE. Above Sea 56 feet.

| Year. | 1877. | 1878. | 1879. | 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | Mean. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January | 1·54 | ·71 | 1·65 | ·00 | 5·79 | 1·06 | 4·88 | ·71 | 2·68 | 5·51 | 2·45 |
| Feb.. .. | ·00 | ·00 | 4·41 | 3·43 | 1·38 | ·95 | 4·57 | ·75 | 7·91 | 1·50 | 2·49 |
| March .. | 5·83 | 1·73 | 6·61 | ·20 | ·75 | 2·13 | 3·66 | 2·72 | 1·02 | 1·65 | 2·63 |
| April .. | 3·47 | (2·95) | (6·00) | 3·58 | 1·73 | 1·10 | 3·90 | 3·31 | 5·43 | 3·23 | 3·47 |
| May.... | 3·27 | 1·93 | 8·03 | 1·50 | 3·27 | 3·23 | 3·11 | 1·06 | 1·73 | 2·09 | 2·92 |
| June .. | 1·34 | ·91 | ·00 | (2·28) | 1·42 | ·08 | 3·19 | 2·60 | 2·05 | ·71 | 1·46 |
| July.... | ·63 | ·08 | ·43 | ·08 | ·00 | ·51 | ·98 | ·00 | 20 | ·12 | ·30 |
| August . | ·04 | ( ·98) | ·71 | 2·79 | 2·72 | ·16 | ·43 | 2·20 | ·75 | 1·42 | 1·22 |
| Sept. .. | ·47 | (3·94) | 4·57 | 3·19 | 4·13 | 7·13 | 1·77 | 3·03 | 1·30 | 1·26 | 3·08 |
| October | 3·50 | 9·65 | ·67 | 2·01 | 4·13 | 14·96 | 3·86 | 1·06 | 7 72 | 7·09 | 5·47 |
| Nov..... | 7·05 | 5·71 | 1·30 | (4·72) | 5·59 | 1·65 | 2·60 | ·59 | 3·98 | 5·55 | 3·87 |
| Dec..... | ·28 | 4·49 | 1·57 | (1·42) | 1·06 | 2·99 | ·59 | 2·20 | ·59 | 3·39 | 1·86 |
| Totals .. | 27·42 | (33·08) | (35·95) | (25·20) | 31·97 | 35·95 | 33·54 | 20·22 | 35·36 | 33·52 | 31·22 |
| Max. Fall | 2·91 | 4·13 | 1·93 | 2·36 | 3·07 | Oct. 28 5·71 Oct. 12 5·16 | 2·79 | | | | |
| Days of Rain | | | | | | 52 | 74 | 40 | 62 | 76 | |

VIII. IX.

| Year. | Nice (Port) Above Sea 30 ft. | Nice (Observatoire), Above Sea 1116 ft. | | | |
|---|---|---|---|---|---|
| | 1880. | 1883. | 1884. | 1885. | 1886. |
| | In. | In. | In. | In. | In. |
| January | ·16 | 3·62 | ( ·79) | 2·17 | 6·58 |
| February | 2·36 | 1·42 | ·83 | 5·83 | 1·50 |
| March | ·00 | 4·02 | 2·28 | 1·06 | 1·38 |
| April | 3·19 | 2·87 | 2·48 | 3·54 | 2·99 |
| May | 1·54 | 2·24 | ·94 | 1·46 | 2·24 |
| June | 2·28 | 2·36 | 3 62 | 2·76 | ·94 |
| July | ·08 | ·20 | ·24 | ·00 | ·28 |
| August | 2·16 | ·43 | ·75 | ·98 | ·75 |
| September | 3·07 | ·55 | 2·01 | ·75 | 1·14 |
| October | 2·13 | ·39 | 1·10 | 10·04 | 6·77 |
| November | 5·04 | ·75 | ·39 | 3·82 | 5·63 |
| December | 1·50 | ·12 | 2·44 | ·83 | 3·98 |
| Totals | 23·51 | 18·97 | (17·87) | 33·24 | 34·18 |
| Max. Fall | | | | 4·25 | 2·76 |
| Days of Rain | | | 57 | 109 | |

X. XI.

| Year. | Villefranche, Above Sea 207 ft. | | | | | | | | | | | Monaco. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1877. | 1878. | 1879. | 1880. | 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | Mean. | 1880. | 1881. |
| | In. | In. | In, | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| January | 1·50 | ·71 | 1·97 | ·12 | 5·28 | ·91 | 4·69 | ·52 | 2·17 | 4·96 | 2·28 | ·20 | 5·63 |
| February | ·00 | ·04 | 3·19 | 2·79 | ·63 | ·43 | 4·02 | 1·10 | 4·53 | 1·38 | 1·81 | 3·27 | ·24 |
| March .. | 7·44 | 1·26 | 5·43 | ·08 | 1·61 | 2·60 | 3·94 | 1·73 | ·87 | 1·50 | 2·65 | ·04 | 1·10 |
| April .. | 2·91 | 3·07 | 6·81 | 3·54 | 1·54 | ·35 | 3·62 | 2·95 | 2·60 | 2·32 | 2·97 | 3·98 | 2·13 |
| May .... | 2·99 | 3·50 | 7·52 | 1·34 | 3·15 | 2·01 | 2·48 | ·47 | 1·65 | 1·58 | 2·67 | 1·69 | 1·81 |
| June .. | ·35 | 1·22 | ·12 | 1·97 | ·35 | ·00 | 1·50 | 2·17 | 1·77 | 1·06 | 1·05 | 1·93 | ·43 |
| July .... | ·32 | ·00 | ·08 | ·00 | ·00 | ·12 | ·16 | ·00 | ·00 | ·00 | 0·07 | ·00 | ·00 |
| Aug..... | ·00 | ·91 | ·08 | 2·01 | 1·61 | ·12 | ·55 | ·20 | ·55 | ·75 | ·68 | 2·60 | ·75 |
| Sept. .. | 1·18 | 4·45 | 4·45 | 2·56 | 4·68 | 5·75 | 1·73 | 1·30 | 2·13 | 1·50 | 2·97 | 3·23 | 1·30 |
| October | 3·94 | 6·58 | 1·06 | 2·13 | 5·75 | 11·18 | 2·87 | 1·02 | 6·06 | 5·24 | 4·58 | 3·35 | 1·97 |
| Nov. .. | 8·54 | 6·38 | 1·42 | 4·13 | 5·39 | 1·06 | 2·09 | ·67 | 4·61 | 6·50 | 4·08 | 4·17 | ·43 |
| Dec..... | ·16 | 3·98 | 1·89 | 1·34 | ·83 | 2·56 | ·00 | ·42 | ·91 | 4·02 | 1·71 | 1·50 | 1·06 |
| Totals .. | 29·33 | 32·10 | 34·02 | 22·01 | 30·82 | 27·09 | 27·65 | 13·55 | 27·85 | 30·81 | 27·52 | 25·96 | 16·85 |
| Max. Fall | 3·31 | 2·95 | 1·97 | 1·42 | 3·15 | 4·80 | 1·65 | | 2·01 | | | 2·01 | 1·14 |
| Days of Rain | | | | | | 49 | 78 | 53 | 75 | 81 | | | |

## Summary of Rainfall Observations at Cannes, 1866-1888.

By M. le Dr. DE VALCOURT.

1866–87, Villa Clara. 1888 Villa Hauterive.

| Year. | 1866. | | 1867. | | 1868. | | 1869. | | 1870. | | 1871. | | 1872. | | 1873. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. |
| | | In. | | In. | | In. | | In. | | In. | | In. | | In. | | In. |
| January .. | 4 | ·89 | 11 | 6·53 | 3 | ·87 | 5 | 1·10 | 8 | 2·46 | 9 | 4·64 | 16 | 8·26 | 13 | 1·66 |
| February .. | 8 | 1·33 | 7 | 4·52 | 1 | ·57 | 5 | 1·65 | 15 | 6·60 | 1 | ·02 | 7 | 2·60 | 6 | 2·38 |
| March .... | 14 | 8·15 | 12 | 4·11 | 5 | 3·92 | 16 | 4·70 | 5 | 2·26 | 8 | 1·16 | 7 | 5·59 | 8 | 3·28 |
| April .... | 8 | 5·04 | 4 | ·56 | 4 | ·86 | 5 | ·94 | 1 | ·83 | 2 | ·23 | 11 | 6·19 | 5 | 3·87 |
| May ...... | 7 | 3·38 | 5 | 1·67 | 8 | ·61 | .. | .. | 0 | ·00 | 8 | 4·60 | 9 | 3·35 | 4 | 1·87 |
| June ...... | .. | .. | .. | .. | 4 | ·82 | .. | .. | 3 | 3·70 | 7 | 3·56 | 0 | ·00 | 7 | ·48 |
| July ...... | .. | .. | .. | .. | 6 | ·61 | .. | .. | 2 | 1·50 | 3 | ·17 | 5 | 1·48 | 0 | ·00 |
| August .... | .. | .. | .. | .. | 4 | ·82 | .. | .. | 4 | ·46 | 2 | ·18 | 2 | ·31 | 0 | ·00 |
| September | 8 | 4·21 | 1 | ·90 | 9 | 9·75 | .. | .. | 2 | ·94 | 7 | 5·94 | 1 | ·20 | 3 | ·75 |
| October .. | .. | .. | 7 | 2·65 | 9 | 8·81 | .. | .. | 2 | 2·05 | 4 | ·99 | 19 | 20·59 | 12 | 8·42 |
| November | 2 | ·28 | 7 | 2·79 | 10 | 5·54 | 5 | 2·41 | 13 | 6·46 | 13 | 10·16 | 7 | 4·00 | 9 | 7·68 |
| December .. | 5 | 2·04 | 7 | 3·75 | 11 | 2·32 | 9 | 6·14 | 16 | 5·28 | 5 | 4·37 | 14 | 13·52 | 2 | ·11 |
| Yearly Total | .. | .. | .. | .. | 74 | 35·50 | .. | .. | 71 | 32·54 | 69 | 36·02 | 98 | 66·09 | 69 | 30·50 |

**Summary of Rainfall Observations at Cannes, 1866-1888.**—*Continued.*

| Year. | 1874. | | 1875. | | 1876. | | 1877. | | 1878. | | 1879. | | 1880. | | 1881. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. |
| | | In. | | In. | | In. | | In. | | In. | | In. | | In. | | In. |
| January .. | 2 | 1·79 | 3 | ·43 | 10 | 2·81 | 4 | 1·47 | 3 | ·43 | 8 | 3·83 | 2 | ·36 | 17 | 5·57 |
| February .. | 6 | 5·18 | 8 | 2·76 | 2 | ·42 | 1 | ·05 | 1 | ·06 | 12 | 2·81 | 7 | 3·02 | 6 | 2·04 |
| March .... | 4 | 1·00 | 5 | ·78 | 8 | 2·64 | 12 | 3·94 | 6 | 1·56 | 13 | 6·37 | 2 | ·16 | 3 | ·51 |
| April ...... | 4 | 4·92 | 8 | 3·21 | 12 | 3·79 | 9 | 2·75 | 8 | 3·27 | 14 | 6·65 | 9 | 3·98 | 8 | 1·57 |
| May ...... | 4 | ·97 | 3 | ·62 | 5 | 2·15 | 7 | 3·54 | 7 | 1·52 | 10 | 5·83 | 6 | 1·89 | 7 | 4·12 |
| June .... . | 2 | ·98 | 11 | 3·21 | 7 | 1·52 | 4 | ·63 | 6 | 1·79 | 1 | ·32 | 5 | 1·96 | 3 | ·59 |
| July ...... | 0 | ·00 | 4 | ·38 | 2 | ·12 | 2 | ·29 | 1 | ·01 | 1 | ·24 | 0 | ·00 | 0 | ·00 |
| August .... | 1 | ·31 | 2 | 1·40 | 4 | 1·06 | 1 | ·08 | 1 | 1·78 | 1 | ·55 | 7 | 2·52 | 4 | 3·71 |
| September.. | 5 | 2·86 | 2 | ·18 | 1 | ·13 | 3 | ·13 | 2 | 1·08 | 8 | 7·81 | 5 | 3·15 | 5 | 2·56 |
| October .... | 7 | 4·98 | 9 | 6·09 | 7 | 3·52 | 5 | 1·37 | 9 | 4·43 | 4 | ·55 | 5 | 1·23 | 9 | 5·12 |
| November .. | 4 | ·76 | 7 | ·67 | 8 | 2·85 | 7 | 2·87 | 13 | 6·42 | 9 | 3·01 | 9 | 6·04 | 6 | 3·63 |
| December .. | 8 | 2·13 | 7 | 1·69 | 11 | 6·57 | 4 | ·26 | 11 | 1·84 | 3 | 1·64 | 4 | ·46 | 7 | 2·63 |
| Yearly Total | 47 | 25·88 | 69 | 21·42 | 77 | 27·58 | 59 | 17·38 | 68 | 24·19 | 84 | 39·61 | 61 | 24·77 | 75 | 32·05 |

| Year. | 1882. | | 1883. | | 1884. | | 1885. | | 1886. | | 1887. | | 1888. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. | Days. | Amount. |
| | | In. | | In. | | In. | | In. | | In. | | In. | | In. |
| January.... | 2 | 1·22 | 11 | 7·76 | 1 | ·59 | 7 | 2·63 | 8 | 4·88 | 6 | 4·14 | 3 | ·68 |
| February .. | 1 | 1·09 | 7 | 3·54 | 6 | 1·12 | 6 | 4·14 | 8 | 2·55 | 5 | 1·93 | 10 | 3·69 |
| March .... | 4 | 1·55 | 9 | 3·33 | 4 | 1·82 | 9 | 1·13 | 5 | 1·80 | 5 | 1·68 | 13 | 5·79 |
| April ...... | 6 | 1·05 | 9 | 4·47 | 10 | 3·57 | 9 | 3·30 | 10 | 2·55 | 4 | 2·94 | 7 | 2·25 |
| May ...... | 7 | 2·13 | 6 | 1·94 | 4 | 1·83 | 4 | 1·34 | 3 | 1·56 | 4 | ·65 | 5 | ·15 |
| June ...... | 0 | ·00 | 5 | 1·20 | 8 | 2·70 | 4 | 4·98 | 6 | ·91 | 3 | 1·00 | 4 | 1·71 |
| July ...... | 5 | ·37 | 2 | ·70 | 3 | ·15 | 0 | ·00 | 3 | ·27 | 4 | 1·02 | 5 | 2·13 |
| August .. | 2 | ·16 | 1 | ·14 | 1 | ·10 | 5 | 1·76 | 4 | 1·73 | 3 | ·38 | 3 | 1·18 |
| September | 8 | 4·23 | 8 | 3·73 | 7 | 2·02 | 4 | 2·32 | 6 | 1·47 | 3 | ·67 | 5 | 1·46 |
| October .... | 9 | 11·08 | 3 | 2·38 | 4 | 2·35 | 10 | 8·07 | 12 | 9·64 | 6 | 3·59 | 4 | 1·15 |
| November .. | 2 | ·72 | 4 | 1·76 | 1 | ·41 | 9 | 4·05 | 11 | 6·22 | 15 | 10·16 | 11 | 11·17 |
| December .. | 9 | 2·42 | 5 | ·55 | 5 | 3·60 | 2 | ·71 | 8 | 2·50 | 5 | 3·04 | 9 | 11·47 |
| Yearly Total | 55 | 26·02 | 70 | 31·50 | 54 | 20·26 | 69 | 34·43 | 84 | 36·08 | 63 | 31·20 | 79 | 42·83 |

**Mean 1868, 1870–88 = 20 years 31·79 ins. Mean 1877–86 = 10 years 28·63 ins.**

| | | |
|---|---|---|
| **Height of Rain Gauge above the ground ........** | **3 ft.** | **3 in.** |
| **" " " sea level ......** | **99** | **0** |
| **Diameter " ........................** | **0** | **10** |

**The gauge was in an open garden, and not at all sheltered by trees or walls.**
**Babinet's Rain Gauge at the same altitude above sea at both places.**

## DISCUSSION.

**The President (Dr. Marcet) remarked that Mr. Symons was exceedingly modest in describing his paper as sketchy, for it was really a useful and valuable communication. He had spent nine successive winters in the Riviera, three at Nice, and six at Cannes, and could confirm what had been said respecting the rainfall being heavier there than in our own country. The wet weather always came with the easterly wind, and frequently quite suddenly. The north-westerly wind, or "Mistral," was the fine weather wind, and he had seen a very cloudy sky become clear within half an hour of the time when the "Mistral" commenced to blow. He did not know any place where the changes of weather**

were so rapid as in the Riviera. He was not in the Riviera when the heavy rainfall in 1882, mentioned by Mr. Symons, was experienced; but he heard about it, and knew that it occasioned very disastrous floods. Fortunately such experiences were rare, and any fear of such a phenomenal rainfall need not deter anyone from wintering in the locality.

Mr. TRIPP remarked that there were two stations on this coast—Marseilles at the western end and Genoa at the eastern end—at which long series of rainfall observations had been made. He had forgotten the actual figures, but it appeared to be a characteristic feature of seaports to have a high range of fall; and he recollected that at these two stations the total for the wettest year was more than twice the average yearly total; and at St. Bernard in the back country at a great elevation the total for the wettest year was nearly three times the mean of a long series of years.

Mr. BREWIN pointed out that the position of Monaco possibly accounted for its getting less rainfall than the other towns in the Riviera, as it projected further from the mountains, and so was less under their influence.

Mr. HARRIES remarked, concerning the exceptionally heavy fall of an inch in twenty minutes at Nice, that heavier falls had been reported in France. On June 22nd, 1889, 1·73 inches fell in 20 minutes at Rochefort, and on the previous day 1·6 inches in 15 minutes at Trampot. On June 6th, 1888, at Frain, 1·65 inches was recorded in 15 minutes; at Toulouse in April, 1841, 1·5 inches; and in March, 1844, 1·58 inches fell in 15 minutes.

Mr. SOUTHALL observed that the greatest falls seemed to occur in the autumn months in the Riviera, whereas in the British Isles the spring months were those in which the heaviest falls were experienced.

Mr. SYMONS, in reply, said that the heavy rainfall at Cannes in October, 1882, was recorded at two stations, and the two returns were consistent with each other. The rainfall in the latter part of the year was heavy, and there were many cases of from 10 to 20 inches in a month.

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REPORT ON THE

# PHENOLOGICAL OBSERVATIONS FOR 1889.

BY EDWARD MAWLEY, F.R.MET.SOC., F.R.H.S.

[Read December 18th, 1889.]

FOR the purposes of this Report I have divided the British Isles into districts differing very slightly from those adopted by the Meteorological Office. For greater clearness these districts have, however, been considered in a reversed order, beginning with the warmer parts of these Islands and proceeding irregularly upwards towards the colder. In order to prevent confusion, the different districts are here indicated by capital letters instead of figures.

The following is the list of stations and observers for the past year (p. 53).

The only station not included in last year's report is that at the Horticultural College, Swanley, Kent. Ireland South (G.) and Scotland East (J.) and North (K.) are altogether unrepresented.

| District. | Station. | County. | Observer. |
|---|---|---|---|
| A. | Babbacombe (Torquay) | Devon | E. E. Glyde |
| „ | Tiverton | Devon | Miss M. E. Gill |
| „ | Westward Ho (Bideford) | Devon | H. A. Evans |
| „ | Usk | Monmouth | C. Mostyn |
| „ | Wells | Somerset | The Misses Livett |
| B. | Killarney | Co. Kerry | Ven. Archdeacon Wynne, D.D. |
| „ | Wicklow | Co. Wicklow | The Misses Wynne |
| C. | Pennington (Lymington) | Hants | Miss E. S. Lomer |
| „ | Buckhorn Weston (Wincanton) | Dorset | Miss H. K. H. D'Aeth |
| „ | Salisbury | Wilts | W. Hussey and E. J. Tatum |
| „ | Swanley (Dartford) | Kent | C. A. Hooper |
| „ | Ealing | Middlesex | A. Belt |
| D. | Oxford | Oxford | F. A. Bellamy |
| „ | Northampton | Northampton | H. N. Dixon |
| „ | Thurcaston (Leicester) | Leicester | Rev. T. A. Preston, M.A. |
| „ | Belton (Grantham) | Lincoln | Miss F. H. Woolward |
| „ | Macclesfield | Cheshire | John Dale |
| „ | Hodsock (Worksop) | Nottingham | Miss A. Mellish |
| E. | Tacolneston (Wymondham) | Norfolk | Miss E. J. Barrow |
| F. | Settle | Yorkshire (West Riding) | S. S. Burlingham and The Misses Thompson |
| H. | Tynron | Dumfries | James Shaw |
| I. | Durham | Durham | H. J. Carpenter |

*The Autumn of 1888.*

The first two months of this season were very cold, dry and sunny, whereas November, on the other hand, proved singularly warm, wet and sunless. Early in October there occurred a series of frosts of exceptional severity for the time of year, which, especially in the Midland counties, did considerable damage to the foliage of trees and gave a sharp check to vegetation generally. Owing to the same cause, the number of wild flowers was after this time very limited, while the autumnal tints were poor and of brief duration. In more favoured localities, however, certain summer-flowering plants came into blossom a second time, and here and there a few spring flowers were also to be seen. This was a very unfavourable season for ripening the wood of fruit and other trees.

*Observers' Notes.*

OCTOBER, 1888.—*Ealing* (C.). 14th. Last swallow seen. *Settle* (F.). 10th. A wild rose was found in full flower on one of the hedges near here.

NOVEMBER.—*Pennington* (C.). Green and golden plover plentiful. Blackbirds and thrushes singing throughout the month. Hedge banks in places bright with Herb Robert and Hare Bells. Wheat sowing much interfered with by rain and on some lands impossible. 6th. Christmas rose in blossom. 14th. Brimstone butterflies seen.

*The Winter of 1888-9.*

Taking the country and also the season as a whole, this was a rather cold, very dry and unusually gloomy winter. In the South of Ireland, in the West of Scotland and also in the North-east of England the weather remained as a rule mild, but in all other districts, after December, it was more or less unseasonably cold. In the Midland and Eastern counties there occurred two rather severe frosts, one at the end of the first week in January and the other about the middle of February. Fortunately, on each occasion these frosts

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1889.

| No. | Name of Plant. | A. England, SW. | | | | | B. Ireland, S. | | C. England, S. | | | | | D. England, Midlands. | | | | | | E. Englnd. E. | F. Englnd. NW. | H. Scotlnd. W. | I. Englnd. NE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Babbacombe. | Tiverton. | Westward Ho. | Usk. | Wells. | Killarney. | Wicklow. | Pennington. | Buckhorn Weston. | Salisbury. | Swanley. | Ealing. | Oxford. | Northampton. | Thurcaston. | Belton. | Macclesfield. | Hodsock. | Tacolneston. | Settle. | Tynron. | Durham. |
| 1 | *Corylus Avellana* | 54 | 19 | .. | 53 | .. | 37 | 45 | 38 | 71 | 32 | .. | 17 | .. | 65 | .. | .. | 78 | 27 | .. | 38 | .. | .. |
| 2 | RANUNCULUS FICARIA | 52 | 42 | 29 | 39 | 51 | .. | 25 | 31 | 18 | 14 | 87 | 73 | 75 | 72 | 32 | 51 | 118 | 48 | 25 | 69 | 93 | 81 |
| 3 | *Mercurialis perennis* | 54 | 31 | 83 | 48 | 52 | .. | .. | 92 | 17 | 52 | 86 | .. | 78 | 82 | 86 | .. | .. | 51 | 83 | 86 | 91 | .. |
| 4 | TUSSILAGO FARFARA | 74 | 70 | 49 | 55 | 71 | 78 | 57 | 60 | 48 | 53 | .. | 76 | 77 | 72 | 88 | 74 | 120 | 72 | 77 | 68 | .. | 45 |
| 5 | *Narcissus Pseudo-narcissus* | .. | 68 | .. | .. | .. | 47 | 58 | 70 | .. | .. | .. | .. | .. | .. | .. | 82 | 113 | 84 | 88 | .. | .. | .. |
| 6 | CALTHA PALUSTRIS | 82 | 100 | 92 | 76 | 78 | 73 | 82 | 89 | 48 | 71 | .. | .. | 91 | 96 | 102 | 95 | 112 | 91 | .. | 103 | 122 | 117 |
| 7 | *Salix caprea* | 51 | 51 | 75 | 75 | 75 | 54 | 60 | 73 | 77 | 57 | .. | .. | 107 | 90 | .. | .. | .. | 83 | .. | 86 | .. | 89 |
| 8 | ANEMONE NEMOROSA | .. | 88 | 92 | 88 | 72 | .. | 88 | 85 | 92 | 75 | .. | .. | .. | 96 | 95 | 89 | 112 | 95 | 94 | 90 | 105 | 100 |
| 9 | *Nepeta Glechoma* | 97 | 96 | 52 | 95 | 91 | 48 | 90 | 107 | 77 | 86 | .. | .. | 107 | 108 | 124 | 101 | 127 | 109 | 90 | 127 | 128 | 115 |
| 10 | PRUNUS SPINOSA | 98 | 102 | 92 | 109 | 107 | .. | 69 | 108 | 116 | 100 | .. | .. | 110 | 121 | 119 | 115 | .. | 108 | .. | 120 | 115 | .. |
| 11 | PRIMULA VERIS | 91 | .. | .. | 113 | .. | 105 | 106 | 109 | 76 | 91 | .. | .. | .. | 110 | 106 | 111 | 120 | 108 | 72 | 119 | .. | 117 |
| 12 | *Cardamine pratensis* | 119 | 101 | 92 | 83 | 107 | 114 | 106 | 95 | 105 | 100 | .. | 122 | 112 | 122 | 117 | 116 | 127 | 117 | 114 | .. | .. | 122 |
| 13 | *Stellaria Holostea* | 105 | 108 | 92 | 108 | 111 | 95 | 115 | 92 | 107 | 101 | 97 | 122 | 121 | .. | 119 | 127 | 120 | 119 | 112 | 127 | 125 | 110 |
| 14 | SCILLA NUTANS | 114 | 108 | 108 | 115 | 90 | 105 | .. | 114 | 103 | 100 | .. | .. | 110 | 112 | 102 | 124 | 128 | 122 | 124 | 121 | .. | 122 |
| 15 | *Ranunculus acris* | 135 | 92 | 126 | .. | 131 | .. | 133 | 128 | 121 | 112 | .. | .. | 114 | 133 | 125 | 130 | 135 | 135 | .. | 130 | .. | .. |
| 16 | *Veronica Chamædrys* | 107 | 92 | 105 | 117 | 121 | 108 | 89 | 107 | 91 | 89 | 97 | .. | 123 | 110 | 129 | .. | 135 | 122 | 123 | 137 | 137 | 122 |
| 17 | *Plantago lanceolata* | 114 | 122 | 107 | 120 | 121 | 108 | 90 | 112 | 100 | 102 | .. | 133 | 122 | 135 | 126 | .. | .. | 125 | .. | 133 | 126 | 139 |
| 18 | *Sisymbrium Alliaria* | .. | 108 | 101 | 115 | 112 | 112 | 99 | 107 | 101 | 110 | .. | 122 | 111 | 127 | 117 | 117 | 135 | 120 | 113 | .. | .. | .. |
| 19 | *Vicia sepium* | 128 | 122 | .. | .. | 115 | 76 | 90 | 135 | 116 | 122 | .. | 160 | 137 | 147 | 137 | .. | 149 | 178 | 138 | 142 | 135 | .. |
| 20 | *Ajuga reptans* | 128 | 117 | 123 | .. | 124 | 127 | 130 | 133 | 114 | 124 | .. | 143 | 131 | 145 | 137 | 134 | 144 | 130 | 131 | 140 | 138 | 140 |
| 21 | GERANIUM ROBERTIANUM | 106 | 107 | 106 | 115 | 113 | 76 | 90 | 114 | 119 | 120 | 131 | .. | 121 | 125 | 134 | 138 | 137 | 129 | 129 | 124 | 137 | 145 |
| 22 | *Syringa vulgaris* | 135 | .. | 128 | .. | 132 | 117 | .. | 132 | 132 | 129 | 137 | 132 | 127 | 134 | 135 | 132 | 141 | 130 | .. | .. | .. | 149 |
| 23 | *Æsculus Hippocastaneum* | 130 | .. | 130 | .. | 134 | 123 | 124 | 129 | 133 | 127 | 131 | 132 | 128 | 130 | 134 | 128 | 140 | 123 | .. | .. | .. | .. |
| 24 | *Galium Aparine* | 141 | 131 | 126 | 159 | 150 | 162 | 141 | 149 | 138 | 136 | .. | 149 | 133 | 141 | .. | 135 | .. | .. | .. | 176 | .. | .. |
| 25 | *Cratægus Oxyacantha* | 139 | 138 | 131 | .. | 137 | 134 | 126 | 137 | 139 | 140 | .. | 136 | 133 | 137 | 140 | 132 | 144 | 134 | 139 | 142 | 150 | 149 |
| 26 | *Cytisus Laburnum* | 136 | .. | .. | .. | 137 | 124 | 134 | 134 | 141 | 134 | .. | 135 | 134 | 146 | 141 | 138 | 143 | 138 | 141 | .. | .. | .. |
| 27 | *Potentilla anserina* | 142 | 151 | 132 | .. | 151 | 135 | 140 | 144 | 137 | 136 | .. | .. | 133 | 151 | 155 | .. | .. | .. | 147 | 154 | 150 | 151 |
| 28 | *Lotus corniculatus* | 140 | 144 | 131 | .. | 135 | 121 | 115 | 141 | 139 | 140 | .. | 145 | 151 | 152 | 156 | .. | 145 | 156 | 150 | 126 | 146 | 147 |
| 29 | *Hieracium Pilosella* | 140 | .. | 148 | 155 | 146 | 140 | 144 | 146 | 141 | 141 | .. | .. | .. | 160 | .. | .. | 157 | .. | 150 | 158 | 152 | .. |

TABLE I.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1889.—*Continued.*

| No. | Name of Plant. | A. England SW. | | | | | B. Ireland, S. | | C. England, S. | | | | | D. England, Midlands. | | | | | | E. England, E. | F. England, NW. | H. Scotland, W. | I. England, NE. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Babbacombe. | Tiverton. | Westward Ho. | Usk. | Wells. | Killarney. | Wicklow. | Pennington. | Buckhorn Weston. | Salisbury. | Swanley. | Ealing. | Oxford. | Northampton. | Thurcaston. | Belton. | Macclesfield. | Hodsock. | Tacolneston. | Settle. | Tynron. | Durham. |
| 30 | TRIFOLIUM REPENS | 153 | 158 | 141 | 155 | 156 | 140 | 117 | 145 | 138 | 142 | .. | 147 | 148 | 150 | 152 | .. | 172 | 138 | .. | 159 | .. | 149 |
| 31 | *Chrysanthemum Leucanthemum* | 141 | 154 | 150 | 160 | 140 | 141 | 135 | 142 | 140 | 145 | .. | .. | 144 | 151 | 154 | .. | 156 | 150 | 150 | 152 | 161 | 163 |
| 32 | *Lychnis Flos-cuculi* | 151 | 152 | 157 | 166 | .. | 156 | 156 | 155 | 139 | 138 | .. | .. | 144 | 152 | 152 | 152 | .. | 168 | .. | 162 | 159 | 165 |
| 33 | *Lathyrus pratensis* | 152 | 161 | 159 | 162 | 159 | .. | 145 | 167 | 146 | 156 | .. | 150 | 163 | 173 | 168 | .. | 170 | 164 | 150 | 130 | 166 | 165 |
| 34 | *Iris Pseud-acorus* | 152 | 165 | 157 | 170 | .. | 137 | 145 | 147 | 163 | 152 | .. | .. | 156 | 166 | .. | 152 | 170 | 154 | .. | 170 | .. | .. |
| 35 | *Rosa canina* | 163 | 161 | 154 | 166 | 154 | 162 | 160 | 157 | 155 | 159 | 156 | .. | 163 | 164 | 154 | .. | 170 | 150 | .. | 162 | 159 | 165 |
| 36 | ACHILLEA MILLEFOLIUM | 168 | 164 | 167 | 175 | 183 | .. | 172 | 170 | 182 | 166 | .. | .. | 175 | 164 | 185 | .. | 170 | 170 | .. | 165 | 181 | .. |
| 37 | MALVA SYLVESTRIS | 164 | 164 | 157 | 166 | 167 | 171 | 159 | 155 | .. | 158 | .. | 170 | 166 | 167 | 164 | .. | .. | 157 | .. | 190 | 166 | 175 |
| 38 | *Stachys sylvatica* | .. | 164 | 140 | 177 | 159 | 170 | 169 | 162 | 149 | 161 | .. | 163 | 163 | 164 | 168 | .. | 163 | .. | .. | 170 | 176 | .. |
| 39 | *Spiræa Ulmaria* | 168 | 168 | .. | .. | 179 | 173 | 172 | 175 | 162 | 165 | .. | .. | 168 | 173 | 172 | .. | 188 | 174 | 172 | 177 | 169 | .. |
| 40 | *Prunella vulgaris* | 153 | 161 | 168 | 175 | 152 | 158 | 160 | 160 | 157 | 169 | .. | 160 | 157 | 167 | 170 | .. | 168 | 172 | .. | 164 | 176 | .. |
| 41 | *Ligustrum vulgare* | 169 | 178 | 178 | .. | 177 | 165 | 160 | 173 | 167 | 159 | .. | .. | 163 | 173 | 180 | .. | 186 | 173 | .. | 195 | .. | .. |
| 42 | *Vicia Cracca* | 169 | 186 | 171 | 170 | 175 | 176 | 172 | 167 | 159 | 169 | .. | .. | 164 | 173 | 178 | .. | 172 | .. | 174 | 162 | 166 | .. |
| 43 | *Senecio Jacobæa* | 182 | .. | 159 | .. | 178 | 180 | 178 | 177 | 139 | 186 | .. | .. | .. | .. | 185 | .. | 190 | 180 | .. | 189 | 181 | .. |
| 44 | CENTAUREA NIGRA | 193 | 164 | 176 | 177 | 173 | 186 | 172 | 178 | 180 | 187 | .. | 173 | 163 | 173 | 178 | .. | 184 | 180 | 172 | 176 | 196 | .. |
| 45 | *Galium verum* | 174 | .. | 180 | .. | 175 | 196 | 178 | 179 | 177 | 176 | .. | 182 | 175 | 173 | 185 | .. | 185 | 180 | .. | 182 | 169 | .. |
| 46 | *Carduus arvensis* | 180 | 186 | 184 | .. | 181 | 179 | .. | 169 | .. | 184 | .. | .. | 159 | 182 | 182 | .. | 190 | 180 | .. | 182 | 181 | .. |
| 47 | CAMPANULA ROTUNDIFOLIA | .. | .. | .. | .. | 201 | 188 | .. | 167 | .. | 193 | .. | .. | .. | 199 | .. | .. | 177 | 188 | .. | 176 | 176 | 178 |
| 48 | *Galeopsis Tetrahit* | .. | .. | 201 | .. | .. | .. | .. | 192 | .. | 214 | .. | .. | .. | 197 | .. | .. | .. | 190 | .. | .. | 181 | .. |
| 49 | CONVOLVULUS SEPIUM | 198 | 168 | .. | .. | 175 | 189 | 197 | 192 | 187 | 188 | .. | 191 | 184 | 189 | .. | .. | 192 | .. | .. | 190 | .. | .. |
| 50 | *Hedera Helix* | 266 | .. | .. | .. | .. | 250 | 290 | .. | .. | 247 | .. | .. | 250 | 264 | .. | .. | .. | 252 | .. | .. | .. | .. |

***English Names of above Plants.***—1. Hazel. 2. Lesser Celandine. 3. Dog's Mercury. 4. Coltsfoot. 5. Daffodil. 6. Marsh Marigold. 7. Great Sallow. 8. Wood Anemone. 9. Ground Ivy. 10. Black-thorn. 11. Cowslip. 12. Cuckoo Flower. 13. Greater Stitchwort. 14. Blue-bell. 15. Upright Crowfoot. 16. Germander Speedwell. 17. Ribwort Plantain. 18. Garlic Hedge Mustard. 19. Bush Vetch. 20. Bugle. 21. Herb Robert. 22. Lilac. 23. Horse Chestnut. 24. Cleavers. 25. Hawthorn. 26. Laburnum. 27. Silver-weed. 28. Bird's Foot Trefoil. 29. Mouse-ear Hawkweed. 30. Dutch Clover. 31. White Ox-eye Daisy. 32. Ragged Robin. 33. Meadow Vetching. 34. Yellow Iris. 35. Dog Rose. 36. Milfoil. 37. Common Mallow. 38. Hedge Woundwort. 39. Meadow-sweet. 40. Self-heal. 41. Privet. 42. Tufted Vetch. 43. Ragwort. 44. Black Knap-weed. 45. Yellow Bedstraw. 46. Field Thistle. 47. Hare-bell. 48. Hemp-nettle. 49. Greater Bind-weed. 50. Ivy.

***Until about the middle of May Wild Flowers were in most districts late in making their appearance, but after this time they came into blossom unusually early.***

TABLE II.—DATE (DAY OF YEAR) OF FIRST SONG AND MIGRATION OF BIRDS, 1889.

| District. | Stations. | Song. | | | | | | | Migration. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Song Thrush. | Nightingale. | Willow Wren. | Chiff-chaff. | Skylark. | Cuckoo. | Turtle Dove. | Flycatcher. | Swallow. | House Martin. | Sand Martin. | Swift. | Goatsucker. | Corncrake. |
| A. | Babbacombe | .. | .. | .. | .. | .. | 117 | 94 | .. | 130 | .. | .. | .. | .. | .. |
| ,, | Usk | .. | .. | 100 | .. | .. | 118 | .. | .. | 102 | .. | 104 | .. | .. | .. |
| B. | Wicklow | .. | .. | .. | 118 | .. | 120 | .. | .. | 98 | .. | .. | 128 | .. | 120 |
| C. | Pennington | .. | 117 | .. | 119 | .. | 103 | .. | .. | 107 | .. | 132 | 129 | 139 | 138 |
| ,, | Buckhorn Weston | .. | 110 | .. | 115 | .. | 108 | .. | 125 | 108 | 100 | .. | 131 | 138 | 140 |
| ,, | Salisbury | .. | .. | .. | .. | .. | 111 | .. | .. | 120 | .. | .. | .. | .. | .. |
| ,, | Swanley | .. | .. | .. | .. | 28 | 111 | .. | .. | 120 | .. | .. | .. | .. | .. |
| ,, | Ealing | .. | 112 | 85 | .. | .. | 114 | .. | .. | 108 | .. | .. | 125 | .. | .. |
| D. | Oxford | .. | .. | .. | .. | .. | 113 | .. | .. | 114 | .. | .. | 124 | 128 | 128 |
| ,, | Northampton | .. | .. | .. | .. | .. | 112 | .. | .. | 109 | .. | .. | .. | .. | .. |
| ,, | Belton | .. | 115 | 117 | 98 | .. | 116 | .. | .. | 112 | 123 | 122 | 132 | .. | 125 |
| ,, | Macclesfield | 48 | .. | .. | .. | 62 | .. | .. | .. | .. | 124 | 126 | 135 | .. | 128 |
| ,, | Hodsock | .. | 120 | .. | 112 | .. | 119 | 127 | 127 | 98 | 124 | 124 | 128 | .. | 123 |
| E. | Tacolneston | .. | 119 | .. | .. | .. | 116 | 128 | .. | 118 | .. | .. | .. | .. | .. |
| F. | Settle | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| H. | Tynron | .. | .. | .. | .. | .. | 118 | .. | .. | 121 | 130 | .. | .. | .. | 128 |
| I. | Durham | 38 | .. | 122 | .. | 45 | 121 | .. | 112 | 112 | 129 | 134 | 132 | .. | 130 |

TABLE III.—DATE (DAY OF YEAR) OF FIRST APPEARANCE OF INSECTS AND FROG SPAWN, 1889.

| District. | Station. | 1. *Melolontha vulgaris.* | 2. *Apis mellifica.* | 3. *Vespa vulgaris.* | 4. *Pieris Brassicæ.* | 5. *Pieris Rapæ.* | 6. *Anthocharis Cardamines.* | Frog Spawn. | Tadpoles. |
|---|---|---|---|---|---|---|---|---|---|
| A. | Usk | .. | .. | .. | .. | 108 | .. | .. | 154 |
| B. | Killarney | 136 | .. | .. | .. | 107 | 140 | .. | .. |
| ,, | Wicklow | .. | .. | 138 | 105 | 136 | 116 | .. | .. |
| C. | Pennington | 134 | 144 | 116 | 134 | 107 | 133 | .. | 145 |
| ,, | Buckhorn Weston | 132 | .. | 121 | 105 | 106 | 136 | .. | .. |
| ,, | Salisbury | .. | .. | .. | 124 | 97 | 140 | 57 | 110 |
| ,, | Swanley | .. | .. | .. | .. | 125 | 141 | .. | .. |
| ,, | Ealing | .. | .. | .. | .. | 126 | .. | 97 | .. |
| D. | Oxford | .. | .. | .. | 135 | 92 | 136 | 93 | .. |
| ,, | Northampton | .. | .. | .. | 128 | .. | .. | .. | .. |
| ,, | Belton | .. | .. | .. | 127 | 119 | 157 | 79 | .. |
| ,, | Macclesfield | .. | 124 | 82 | 139 | 124 | .. | .. | .. |
| ,, | Hodsock | .. | 163 | 114 | 145 | 126 | 138 | .. | .. |
| E. | Tacolneston | .. | .. | .. | .. | .. | 129 | 91 | .. |
| I. | Durham | .. | .. | 108 | 153 | 138 | 140 | 84 | .. |

*English Names of above Insects.*—1. Cock Chafer. 2. Honey Bee. 3. Wasp. 4. Large Cabbage Butterfly. 5. Small Cabbage Butterfly. 6. Orange-tip Butterfly.

lasted only a few nights, and the weather being dry at the time, but little injury was done by them. Indeed, as regards both farm and garden crops, they served to give a wholesome check to their growth, which, owing to the great mildness of November and December, was becoming dangerously forward. In many parts of the country, however, no frosts worth mentioning

TABLE IV.—ESTIMATED YIELD OF FARM CROPS IN 1889.

| Description of Crop. | England. | | | | | |
|---|---|---|---|---|---|---|
| | A. SW. | C. S. | D. Mid. | E. E. | F. NW. | I. NE. |
| Wheat | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. |
| Barley | O. Av. | O. Av. | U. Av. | O. Av. | Av. | O. Av. |
| Oats | O. Av. | O. Av. | U. Av. | O. Av. | Av. | U. Av. |
| Corn Harvest began, average Date, | 222 (Aug. 10) | 215 (Aug. 3) | 227 (Aug. 15) | 218 (Aug. 6) | 224 (Aug. 12) | 226 (Aug. 14) |
| Beans | U. Av. | Av. | U. Av. | U. Av. | .. | Av. |
| Peas | Av. | Av. | U. Av. | Av. | .. | Av. |
| Potatoes | O. Av. | O. Av. | O. Av. | Av. | O. Av. | Av. |
| Turnips | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | Av. |
| Mangolds | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. |
| Hay | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. |

| Description of Crop. | Scotland. | | | Ireland. | British Isles. |
|---|---|---|---|---|---|
| | H. W. | J. E. | K. N. | B. and G. S & N. | |
| Wheat | O. Av. | O. Av. | .. | O. Av. | O. Av. |
| Barley | .. | Av. | .. | O. Av. | O. Av. |
| Oats | O. Av. | U. Av. | U. Av. | Av. | Av. |
| Corn Harvest began, average Date | 234 (Aug. 22) | 238 (Aug. 26) | 339 (Aug. 27) | 228 (Aug. 16) | 227 (Aug. 15) |
| Beans | .. | .. | .. | .. | U. Av. |
| Peas | .. | .. | .. | .. | U. Av. |
| Potatoes | O. Av. | O. Av. | Av. | Av. | O. Av. |
| Turnips | O. Av. | Av. | Av. | Av. | O. Av. |
| Mangolds | .. | .. | .. | O. Av. | O. Av. |
| Hay | O. Av. | O. Av. | U. Av. | Much O. Av. | Much O. Av. |

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Agricultural Gazette* at the end of the Summer.

occurred until the middle of the last month of the quarter. In these districts there was throughout the whole winter a fair sprinkling of wild and garden flowers to be seen.

*Observers' Notes.*

DECEMBER.—*Babbacombe* (A.). Owing to the unusual mildness of the season, birds were singing, trees budding and many flowers in blossom throughout the month. *Pennington* (C.). Primroses out in woods and lanes; throughout the month, and in the gardens periwinkle and polyanthus also in blossom. 5th. Chaffinch singing. 6th. Brimstone Butterfly seen. 28th. A blackberry blossom gathered. *Macclesfield* (D.). The gardens looked fresh at Christmas and the grass greener than I remember it to have been at that time of year.

JANUARY, 1889.—*Babbacombe* (A.). Owing to the absence of severe frost, many flowers, including roses, were in bloom, while birds were singing throughout the month. *Wicklow* (B.). A very mild month. Crocuses out in the borders during the last week, also quantities of primroses and wallflowers. The Abutilon in flower all the winter. Thrushes have had their full song all this month, like as in spring. *Pennington* (C.). Wild flowers unusually plentiful and birds singing. Plover scarce. 1st. Primroses, polyanthuses, periwinkles, wallflowers and garden anemones in bloom. 15th. Daphne laurels in blossom. 20th. Barren strawberry in flower—earliest date since 1884, when it was out on the 9th.

TABLE V.—ESTIMATED YIELD OF FRUIT CROPS IN 1889.

| Description of Crop. | England. | | | | | |
|---|---|---|---|---|---|---|
| | A. SW. | C. S. | D. Mid. | E. E. | F. NW. | I. NE. |
| Apples | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Pears | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Plums | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | .. |
| Raspberries | O. Av. | O. Av. | O. Av. | O. Av. | Av. | O. Av. |
| Currants | O. Av. | O. Av. | O. Av. | O. Av. | Av. | Av. |
| Gooseberries | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. |
| Strawberries | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. |

| Description of Crop. | Scotland. | | | Ireland. | British Isles. |
|---|---|---|---|---|---|
| | H. W. | J. E. | K. N. | B. and G. S & N. | |
| Apples | | U. Av. | | U. Av. | U. Av. |
| Pears | | U. Av. | | U. Av. | U. Av. |
| Plums | | O. Av. | | Av. | U. Av. |
| Raspberries | | O. Av. | | O. Av. | O. Av. |
| Currants | | O. Av. | | O. Av. | O. Av. |
| Gooseberries | | O. Av. | | O. Av. | O. Av. |
| Strawberries | | Much O. Av. | | Much O. Av. | Much O. Av. |

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

23rd. Snowdrop in blossom. 31st. Celandine in bloom—earliest date for six years. *Buckhorn Weston* (C.). A great quantity of primroses in blossom, not only in sheltered nooks but in more exposed places. Thrushes have been singing all the month, and I have found two blackbirds' nests in process of building. Rooks, too, have begun to build. *Salisbury* (C.). Up to the end of the month, no frog spawn had been seen. 21st. No fertile flowers of the Hazel could be found. Catkins unusually small. Vegetation generally was, at this time, by no means remarkably forward. *Hodsock* (D.). At the end of the month a few snowdrops and aconites were in flower, also a few primroses. 27th. Both barren and fertile flowers of the Hazel in blossom.

FEBRUARY.—*Usk* (A.). Have noticed comparatively few fieldfares this year. *Pennington* (C.). Vegetation made scarcely any progress during this month. 9th. A pear in blossom—a solitary flower. 25th. Yew in blossom. *Macclesfield* (D.). 2nd. A change to colder weather. Many plants were killed—wallflowers, pansies, &c. 8th. Heavy snow storm, the branches of many trees and shrubs broken by the weight of snow. Plum trees and Scotch firs suffered most. *Hodsock* (D.). Snowdrops in full flower. *Tacolneston* (E.). 2nd. Pyrus Japonica, with a good many flowers open, on a sheltered south wall. These blossoms were, however, destroyed by frost during the second week.

## *The Spring of 1889.*

This was in all districts a more or less cold spring, with a heavy rainfall and a considerable amount of bright sunshine. Early in March there occurred in most localities an unusually severe frost. Indeed, the weather was then in many places colder than at any time during the three previous winter months. The only districts which appear to have escaped this frost

were Ireland South and England South-west and West. During April no damaging cold was recorded, but throughout a great part of the month low temperatures prevailed almost everywhere. The absence of night frosts in May was the most marked characteristic of that month, and as affecting vegetable growth the most noteworthy feature of the year. Until the end of April vegetation was almost everywhere very backward, but the warm showery weather which May brought with it wrought a complete change, and from this time a very rapid advance was made. The foliage of trees at the close of the season was remarkably luxuriant. Several observers, both in the warmer as well as the colder districts, mention the absence of bloom on the beech and ash. On the other hand, the blossom on such fruit trees as apples, pears, cherries, &c., proved unusually abundant. Nevertheless, on close examination these blossoms were found to be in many cases imperfectly formed, while the young leaves suffered greatly from the ravages of caterpillars and aphis. As regards birds, the spring migrants seem everywhere to have been less numerous than usual, and to have been, moreover, late in making their appearance.

### *Observers' Notes.*

MARCH.—*Babbacombe* (A.). 27th. Hawthorn in leaf. *Usk* (A.). Vegetation generally stationary after about the 20th, owing to cold weather. *Wells* (A.). Vegetation backward, not so much from prolonged or severe cold as from absence of sunshine and cold dampness. *Pennington* (C.). Spring sowing on heavy soil very backward by end of month, owing to frequent rains. 16th. Darwinii Berberis in flower. 26th. Missel Thrush's nest, with two eggs in it. 29th. Saw one Peacock, three Brimstone and two small Tortoiseshell butterflies. *Salisbury* (C.). 22nd. Peach in blossom. 31st. The first water spider seen. *Ealing* (C.). The garden spring flowers are backward. Crocuses were not abundant till the 13th. *Northampton* (D.). There having been but very little sunshine and not many warm days, vegetation was very backward at the end of the month. *Hodsock* (D.). 19th. Eggs in Thrush's nest. 29th. A few green leaves on Hawthorn in sheltered places.

### *The Summer of 1889.*

The summer of the past year was, on the whole, a cold, wet and sunless one. Throughout June the weather continued changeable, but for the most part warm and summer like. The record of sunshine was, moreover, large, while very little rain fell after the first week. On the other hand, during nearly the whole of July and August the temperature ruled persistently low, and there was comparatively little bright sunshine. The total rainfall in these two months was not much in excess of the average; but then, again, there occurred very few fine days. During June and the first half of July vegetation generally was very forward, and the hedgerows, fields and woods were even gayer than is usual at this season with wild flowers. The crop of hay proved an abundant one, and nearly the whole of it was harvested early and in splendid condition. The drought which prevailed in most districts during the latter half of June and the early part of July was at the end of this period becoming much felt, so that the moister and cooler weather which followed was at first greatly welcomed. Unfortunately, however, for the cereals, and more particularly for the wheat crop, these cooler conditions

lasted, almost without a break, until the close of the summer, while storms of rain were here and there at times exceptionally heavy. Where the rainfall was lightest many deciduous trees were, in the latter part of August, already beginning to lose some of their foliage. The corn harvest, notwithstanding many interruptions from rain, was in some of the earliest districts completed before the close of the summer; in fact, in most other places a great deal of corn had been carried before the month of August came to an end. This was a splendid summer for roots and all kinds of vegetables.

*Observers' Notes.*

JUNE.—*Babbacombe* (A.). Haymaking began on the 13th. The crop was heavy, and the dry weather in the latter half of the month was most favourable for its ingathering. Vegetation was very forward. *Westward Ho* (A.). 9th. This was the only really wet day. *Pennington* (C.). Roses were at their best before the end of the month. Flowers on elder abundant. No turnip fly. The Nightingale finished its song at the beginning and the cuckoo by the middle of the month. Wheat promising well at end of month. 10th. Pasture grass cut; carried by the 28th; 40 acres in all. 11th. Gathered first strawberry. 26th. Gathered first raspberry. *Buckhorn Weston* (C.). Hay crop very early and abundant, and harvested in good condition. Great quantity of blight of every sort, and foliage much injured. Very few swallows indeed; also very few martins. *Oxford* (D.). Hay excellent in quantity and quality. It is many years since there was so good a crop. Wild flowers very plentiful. 2nd. Acacias (Robinias) in full leaf. 12th. Cuckoo last heard. *Northampton* (D.). Hay crop got in very successfully *Macclesfield* (D.). Vegetation up to the last week never looked better in Cheshire. Grass crops unusually heavy. First grass cut on 12th. By the end of the month fully one-half the hay had been secured, mostly without rain. Apples falling numerously at the end of the month through drought. *Tynron* (H.). Vegetation very forward. Scarcely any rain during the last three weeks.

JULY.—*Babbacombe* (A.). The abundant rain from the 7th to 25th did great good to the pastures, which had become parched through the long drought. *Pennington* (C.). Harvest operations commenced on the 13th. *Buckhorn Weston* (C.). July has been throughout wet and cold. *Macclesfield* (D.). Leaves of the lime beginning to fall on the 29th, owing to the recent drought. Meadows and pastures very brown until towards the middle of the month.

AUGUST.—*Babbacombe* (A.). Wheat was cut on the 6th and harvest finished by the 31st. The yield was good. *Pennington* (C.). The ingathering of the harvest, which commenced early, was much retarded by the rainy weather. 24th. Finished carrying wheat. 29th. Harvest finished. *Hodsock* (D). Corn all cut by the end of the month, and about half of it carried. A good many leaves falling, especially from the beeches, at the end of the month.

*The Year ending August 1889.*

Taking the country generally, the most noteworthy features of the weather of the past phenological year, as affecting vegetable life, may be briefly summed up as follows:—1. The unseasonably sharp frosts and continued cold in October, which gave a sudden and premature check to vegetation generally. 2. The moist warmth of November, which started all things growing again. 3. The absence during the winter of any cold period of sufficient duration to arrest this renewed growth. 4. Some severe frosts in March, which at last brought everything more or less to a standstill. 5. A frostless May and brilliant June, which enabled all the new growths to be made without the slightest check or injury. 6. A persistently cold, wet and gloomy July and August, which at first did much good by bringing to an end a drought which at one time threatened to become serious, but which afterwards served to

undo much that the bright and genial weather of the two previous months had succeeded in accomplishing.

Taken as a whole, this proved an unusually gay and bountiful year.

## DISCUSSION.

The PRESIDENT (Dr. Marcet) said that these reports were always interesting, and as the Rev. T. A. Preston had given up the work of discussing these Phenological observations, Mr. Mawley had undertaken to go on with it, so that these reports could still be looked for.

Mr. SOUTHALL expressed his satisfaction with Mr. Mawley's report, as it pointed out in a clear manner what he had himself been able to observe concerning the progression of the seasons. Mr. Mawley had mentioned that there were no frosts in May during the past season, but in his own locality (Ross) no frosts were experienced from March 26th until the middle of October.

Mr. MAWLEY said that it was, of course, impossible to compare the observations given in the table of Flowering Plants in the same way that observations taken with meteorological instruments could be compared, but that nevertheless many interesting particulars respecting the character and progress of the seasons and their influence on vegetation might be obtained from this table and the observers' notes.

# SUNSHINE.

BY ALEX. B. MACDOWALL.

[Read November 19th, 1889.]

As the records of sunshine accumulate, new points of view of the phenomenon are from time to time obtainable. In the *Meteorological Record* we have monthly data of sunshine from 24 stations (end of 1888), most of them using the Campbell-Stokes instrument, but a few (Buxton, Wallington, Stowell, Torquay) that of Jordan, which is understood to record, when measured before development, about 11 per cent. more sunshine than the other.

We may find it useful to make out a curve of the sunshine at one of those stations for a series of years, and for this purpose I select Southbourne-on-Sea, a new watering place near Christchurch, in Hants (where Dr. Compton is the observer). It stands high in the list of comparative sunshine, and furnishes a nearly continuous curve from the beginning of 1881, as in the diagram (Fig. 1). A dotted line curve is added for a northern station—Llandudno. While corresponding with the other to some extent, less sunshine is evidently the rule at this station.

The sunniest year of this Southbourne record is 1887 (Jubilee year), when 1,822 hours were recorded; the least sunny, 1888, with 1,328. The curve, it will be seen, varies considerably from year to year. How unlike are the curves for the two years just referred to!

Taking the averages of the monthly figures in the nine years, 1880-88, we have the following series for seven months of the year:—

| April. | May. | June. | July. | Aug. | Sept. | Oct. |
|---|---|---|---|---|---|---|
| 15 | 218 | 197 | 214 | 198 | 188 | 104 |

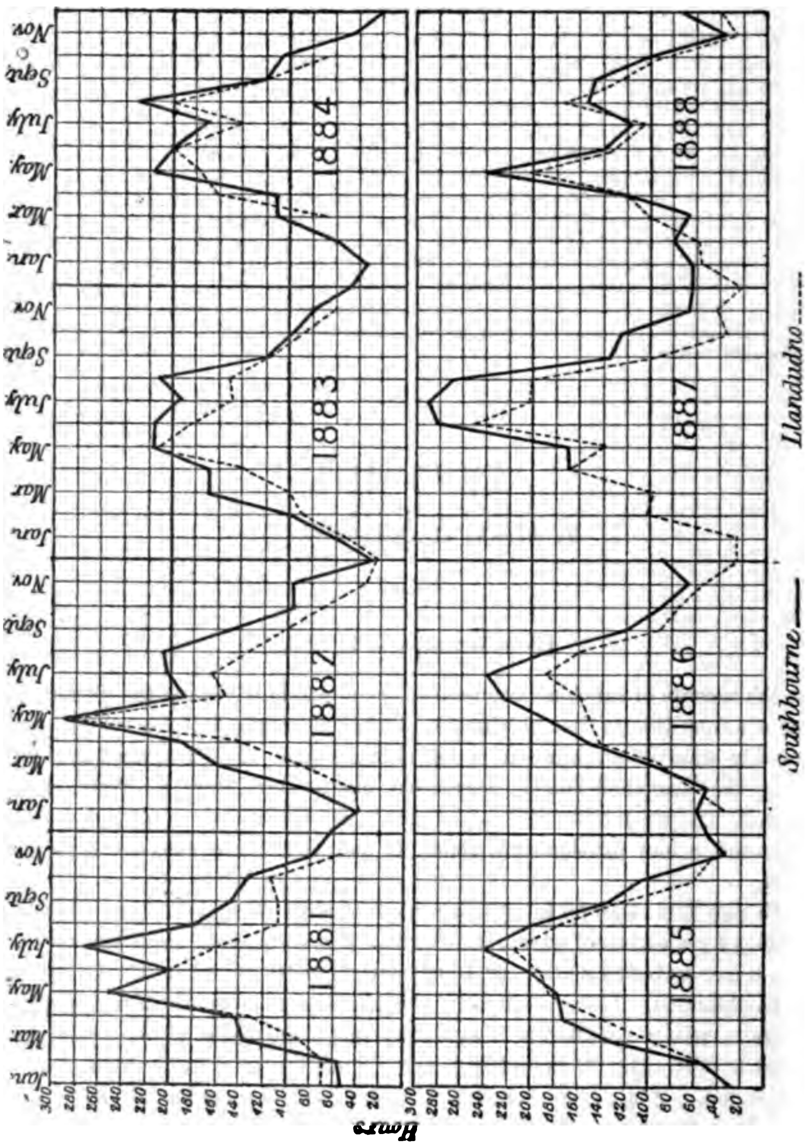


FIG. 1.—Sunshine at Two Stations in Eight Years, 1881-8.

This gives two maxima, viz. in May and July, that in July being but slightly under that in May. Regarding this series for a moment as approximately the type (and the time considered is of course rather short), we may note

how not one of the annual curves here given corresponds closely with the typical one. In some years there is but one maximum; and while in most there are two, these occur, in four of the years, in May and August respectively. In 1881 they fall in May and July, but that in July is the greater.

The occurrence of two maxima seems to be usual; and while there is only a suggestion of the earlier maximum in the Southbourne curve for 1887, we find this maximum quite evident in the curves for some other places, shown in Fig. 2. These four stations (Blackpool, Buxton, Eastbourne, and St.

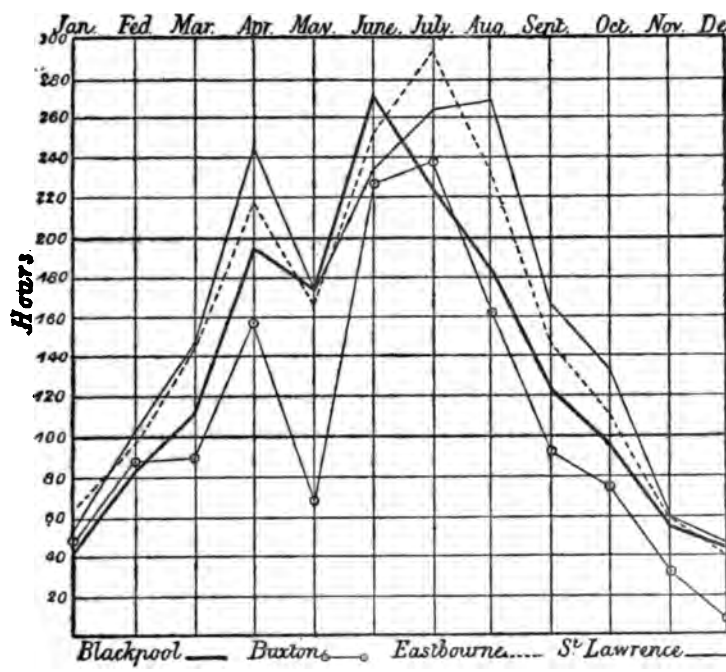


FIG. 2.—Sunshine at Four Stations, 1887.

Lawrence, Ventnor), are pretty far apart from each other, and they all show an early maximum in April; but the second, and in this year higher, maximum, appears for Blackpool in June, for Eastbourne and Buxton in July, and for St. Lawrence in August. This diagram shows further the general inferiority of Buxton, in the amount of sunshine this year, to the other three stations; and while Eastbourne attained the highest monthly amount, the values for St. Lawrence are generally higher than those for Eastbourne.

The following is a list of the 20 stations, yielding records in 1887, in the order of amount of sunshine for that sunny year, along with a similar list of same stations for the sunless year 1888:—

| 1887. | Hours. | 1888. | Hours. |
|---|---|---|---|
| 1. Rousdon .. .. | 1933 | 1. Eastbourne .. .. | 1461 |
| 2. St. Lawrence .. | 1902 | 2. St. Lawrence .. | 1441 |
| 3. Eastbourne .. .. | 1829 | 3. Rousdon .. .. | 1412 |
| 4. Southbourne .. | 1822 | 4. Southbourne .. | 1328 |

| 1887. | Hours. | 1888. | Hours. |
|---|---|---|---|
| 5. Cullompton .. .. | 1784 | 5. Hillington .. .. | 1309 |
| 6. Harestock .. .. | 1761 | 6. Harestock .. .. | 1282 |
| 7. Church Stoke .. | 1698 | 7. Newton Reigny .. | 1246 |
| 8. Hillington .. .. | 1677 | 8. Church Stoke .. | 1216 |
| 9. Blackpool .. .. | 1596 | 9. Llandudno .. .. | 1210 |
| 10. Kew .. .. .. | 1592 | 10. Cullompton .. .. | 1206 |
| 11. Berkhamsted .. | 1569 | 11. Aspley Guise .. | 1191 |
| 12. Aspley Guise .. | 1566 | 12. Blackpool .. .. | 1173 |
| 13. Newton Reigny .. | 1476 | 13. Kew .. .. .. | 1157 |
| 14. Hodsock .. .. | 1420 | 14. Greenwich .. .. | 1068 |
| 15. Greenwich .. .. | 1401 | 15. Hodsock .. .. | 1065 |
| 16. Llandudno .. .. | 1376 | 16. Berkhamsted .. | 1045 |
| 17. Southwell .. .. | 1337 | 17. Southwell .. .. | 1040 |
| 18. Buxton .. .. | 1257 | 18. Bunhill Row .. | 911 |
| 19. Bolton .. .. | 1132 | 19. Buxton .. .. | 819 |
| 20. Bunhill Row, London | 1083 | 20. Bolton .. .. | 787 |

The order is evidently very much the same. The greatest difference is Llandudno—16th in one list, 9th in the other; then come Newton Reigny 13th and 7th, Cullompton 5th and 10th, &c. The values of the first list are in general reduced in the second by about a fourth.

In a paper on "Measurement of Sunshine," read to the Society on March 18th, 1885, Mr. Scott discussed the records of sunshine for five years or less at a large number of stations, including some in Scotland and Ireland. He noted, *inter alia*, an absolute maximum in May, and a second maximum for the South of England in August.

Longer series of observations being now available, the present paper chiefly aims at showing further how the phenomenon in question has varied recently from year to year at a selected station, and how it has varied in a selected year at some different places.

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# PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

## November 20th, 1889.

### Ordinary Meeting.

William Marcet, M.D., F.R.S., President, in the Chair.

William Waters Butler, Crown Brewery, Birmingham;
John Edward Cullum, Valentia Observatory, Co. Kerry;
John Dover, B.A., Elmfield, Totland Bay, Isle of Wight;
Richard Gorton, Claremont Place, Cirencester;
Ralph Heap, M.A., Brick Court, Temple, E.C.;
Vincent Alexander Lawson, C.E., 9 Rowcroft, Stroud;
Edward Musgrove, Junr., The Hollies, Sidcup;
John Rose-Innes, B.A., B.Sc., 148 Kensington Park Road, W; and
John Clough Thresh, D.Sc., M.B., The Limes, Chelmsford,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"Second Report of the Thunderstorm Committee.—Distribution of Thunderstorms over England and Wales, 1871-1887." By William Marriott, F.R.Met.Soc. (p. 1.)

"ON THE CHANGE OF MEAN DAILY TEMPERATURE WHICH ACCOMPANIES THUNDERSTORMS IN SOUTHERN ENGLAND." By G. M. WHIPPLE, B.Sc., F.R.Met.Soc. (p. 12.)

"NOTE ON THE APPEARANCE OF ST. ELMO'S FIRE AT WALTON-ON-THE NAZE, SEPTEMBER 3RD, 1889." By W. H. DINES, B.A., F.R.Met.Soc. (p. 15.)

"NOTES ON CIRRUS FORMATION." By H. HELM CLAYTON. (p. 16.)

"A COMPARISON BETWEEN THE JORDAN AND THE CAMPBELL-STOKES SUNSHINE RECORDER." By F. C. BAYARD, LL.M., F.R.Met.Soc. (p. 20.)

"SUNSHINE." By A. B. MACDOWALL. (p. 61.)

"ON CLIMATOLOGICAL OBSERVATIONS AT BALLYBOLEY, CO. ANTRIM." By Prof. S. A. HILL, B.Sc., F.R.Met.Soc. (p. 24.)

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DECEMBER 18TH, 1889.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

GUSTAV VALENTIN ALSING, C.E., St. Paul's Chambers, Sheffield;
Col. WILLIAM FRANCIS BADGLEY, Kyrewood House, near Tenbury;
GEO. RUSSELL BEARDMORE, L.R.C.P., Warwick House, Upper St., Islington, N.;
GEORGE DAVID BELLAMY, C.E., 8 Gordon Terrace, Plymouth;
HENRY FRANKLIN BELLAMY, C.E., Selangor, Malay Peninsula;
Capt. WILLIAM A. BENTLEY, R.A., Hurdlestown, Broadford, Co. Clare;
W. LONGLEY BOURKE, C.E., Westbrook, Eccles, Manchester;
JAMES COLLIE, C.E., Burgh Hall, Dunoon;
JOHN BREEDON EVERARD, C.E., 6 Millstone Lane, Leicester;
THOMAS FENWICK, C.E., Chapel Allerton, near Leeds;
HENRY GALE, C.E., F.R.G.S., 45 Elvaston Place, Queen's Gate, S.W.;
SAMUEL GRIFFIN, C.E., Kingston Iron Works, Bath;
Prof. MARK W. HARRINGTON, M.A., Ann Arbor, Michigan, U.S.A.;
WILLIAM WILSON HULSE, C.E., Withington, Manchester;
JAMES EDWARD LINGARD, C.E., 5 Normanton Road, Derby;
L. LIVINGSTONE MACASSEY, C.E., Stanleigh, Holywood, Belfast;
Surgeon-Major JOHN ALEXANDER MCCRACKEN, St. Ann's Garrison, Barbados;
FRANK MASSIE, C.E., Tetley House, Kirkgate, Wakefield;
FRANK MEAD, C.E., Sutton, Surrey;
RICHARD R. MENNEER, C.E., Indian Public Works, Sind, India;
JOSEPH MITCHELL, C.E., Bolton Hall, Bolton-on-Dearne, near Rotherham;
FRANK MORRIS, C.E., Brentford Lodge, Old Brentford;
BONNER HARRIS MUMBY, M.D., Iver Lodge, Merton Road, Southsea;
WILLIAM BESWICK MYERS, C.E., F.G.S., 75 Avenue Road, N.W.;
WILLIAM J. NEWTON, C.E., Town Hall, Accrington;
JOHN PARKER, C.E., Nelson Villa, Hereford;
Sir ROBERT RAWLINSON, K.C.B., C.E., 11 The Boltons, West Brompton, S.W.;
ISAAC SHONE, C.E., 50 Nevern Square, S.W.;
Capt. JOHN SHORTT, R.N., Hobart, Tasmania;
HENRY SIMON, C.E., 20 Mount Street, Manchester;
JOHN GODFREE SINGLE, C.E., 7 Morley Street, Plymouth;
Maj.-Gen. FREDERICK SMITH STANTON, R.E., The Grove, Hillingdon, Uxbridge;
THOMAS WILLIAM STONE, C.E., 189 Goldhawk Road, W.;
JOHN HARRIS HAZLETT SWINEY, B.A., C.E., 6 Chichester Avenue, Belfast;
ROBERT LETHBRIDGE TAPSCOTT, C.E., 41 Parkfield Road, Liverpool;
GEORGE WALLER WILLCOCKS, C.E., 9 Hume Street, Dublin;
JOHN AVERY BRANTON WILLIAMS, C.E., Queen's Chambers, Cardiff;
EDWARD WOODS, C.E., 45 Onslow Gardens, S.W.; and
Capt. NICOLAS ZELENOI, Beaufort Mansions, Queen Anne's Gate, S.W.,
were balloted for and duly elected Fellows of the Society.

Mr. J. S. HARDING and Mr. H. S. WALLIS were appointed Auditors of the Society's Accounts.

The following Papers were read :—

"REPORT OF THE WIND FORCE COMMITTEE ON THE FACTOR OF THE KEW PATTERN ROBINSON ANEMOMETER." Drawn up by W. H. DINES, B.A., F.R.Met.Soc. (p. 26.)

"ON TESTING ANEMOMETERS." By W. H. DINES, B.A., F.R.Met.Soc. (p. 41.)

"ON THE RAINFALL OF THE RIVIERA." By G. J. SYMONS, F.R.S., F.R.Met.Soc. (p. 44.)

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1889." By EDWARD MAWLEY, F.R.Met.Soc. (p. 52.)

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# CORRESPONDENCE AND NOTES.

"SQUALL AT DOVER, AUGUST 5th, 1846." By ROBERT LAWSON, LL.D., F.R.Met.Soc., Inspector-General of Hospitals.

THE following description of an extensive squall, which I witnessed at Dover forty-three years ago, may even yet prove interesting to the Fellows of the Royal Meteorological Society. This occurred on August 5th, 1846, and the account of the appearances, which is given below verbatim, was drawn up on the 8th, while the details were fresh in the memory.

While going over the heights between the Barracks and Hospital, on the morning of the 5th, about a quarter before 9 a.m., I was struck with the rate at which a ship about 1½ mile off shore going south was running; she was under topsails, topgallants, courses, and jib; in a few minutes (not above 2 or 3) the breeze increased so much that she was obliged to let fly her topgallant sheets, let go her topsail halyards, and, notwithstanding, bear up immediately. At this time there was a long line of cloud, extending from the South Foreland off about South-south-west by compass, for 6 or 8 miles; this was in rapid motion, whirling and turning on itself, and was about perpendicular to the ship mentioned. There was a ripple on the water from the vessel towards the shore about a mile at the time she bore up; inside this ripple the water was then smooth, and on the height where I then was there was no wind. At this time I noticed a slight whirlwind, just on the line between the smooth and rough water, which carried up a spray for about 50 feet and then ceased; the spray distinctly whirled against the sun, there was no cloud formed at its top, it lasted not a quarter of a minute. Seven or eight minutes afterwards the cloud previously mentioned had increased considerably, and masses of vapour from it were flying above right towards the land, while below the breeze quickly extended to the shore blowing off the land, and freshened rapidly. In less than ten minutes afterwards a slight shower fell, after which the clouds all cleared away, and a brisk breeze came on from the northward.

The previous night there had been a violent thunderstorm; early in the morning the wind was about North-east by compass, slight, weather overcast, close, and rather hazy. At a quarter to 9 there was a pretty general stratum of cirro-stratus moving very slowly from about South-west, between which and the cloud mentioned above was an extensive interval; the weather then, too, was pretty clear. There was no lightning seen nor thunder heard during the above. The squall extended for a long way under the cloud, as was obvious from vessels shortening sail and bearing up, though it nowhere seemed so violent as right off the height I was on. The wind at the Castle (a mile off), as was evident from the fly of the Jack there, was off the land, while the clouds over it were flying inland. The whole phenomenon scarcely occupied 20 minutes. I did not detect the direction of the wind in the offing beyond the cloud.

HEAVY RAINFALL IN CLARE AND GALWAY, IRELAND, ON SEPTEMBER 1ST, 1887.
By CAPT. W. A. BENTLEY, R.A., F.R.Met.Soc.

I HAVE made exhaustive inquiries as to the rainfall of September 1st, 1887, in the counties of Clare and Galway. I wrote to nearly every person who I thought could give any information on the subject, and the replies I received were all more or less of an interesting nature.

The rain-gauges in Clare are situated on a line which runs nearly east and west through the country—from Killaloe on the east to Miltown Malbay on the west. There are no gauges north of this line in Clare.

The county Galway gauges are nearly all on a line, which also runs nearly east and west. The railway from Ballinasloe to the City of Galway marks approximately the position of this line. There are no gauges in Galway south of it, but north of it there are five, viz. three in the neighbourhood of Tuam and two at Kylemore Castle, which is about two miles east of Letterfrack.

The great rainfall of September 1st, 1887, was a very remarkable one, for both the morning and the evening of that day were fine at nearly every station that has sent me a report. The principal fall took place on a line drawn from Loop Head to the City of Galway. The observer at Miltown Malbay reports: "The morning opened very fine, so that I was induced to put my men at hay-making. The sky was quite clear, and not a cloud was to be seen. At 10 a.m. two clouds commenced to form well above the horizon, not larger at this time than good-sized haystacks. One was to the south-west over Loop Head, and the other was a few points north of it. Such wind as there was at the time was from the North-west. The two clouds rapidly increased in density and volume. The wind suddenly backed to the South-west, but the force was not much increased. The rain began at 11 a.m. and ended at 3 p.m. Between those hours there were two breaks in the rain; in fact, the rain on that day consisted of three great showers. I estimated the breadth of the dark cloud as from four to five miles. The rain came down in torrents. In a short time every hollow in the ground was converted into a lake, and all the low flat lands were under water. I lay at full length on the ground longside a five-foot stone wall for shelter. Not a drop of rain touched me; but I was wet to the skin in less than ten minutes with the spray from the top of the wall and from the ground longside me. The heavy part of the rainfall from the centre of the dark cloud did not cover a frontage of more than 1¼ miles."

The cloud passed over Burren in the direction of Galway City. In the neighbourhood of Lisdoonvarna a bridge was carried away by a flood that afternoon, and a horse wandering on the public road near Lemenagh Castle was drowned. The gauge at Miltown Malbay recorded a fall of 2·05 inches.

At the Court House at Ennis it rained for 12 hours on that day, but the fall was not a heavy one, being only ·60 in. The first five days of September 1887 were very wet at Ennis; 3·30 ins. of rain fell during that time.

At Kilkishen Glebe there was a much larger rainfall than at Ennis, ·97 in. being the record there.

My gauge at Hurdlestown recorded a fall of ·56 in. on that day. I regret I cannot give any information as to the duration of the rain, or to the direction of the wind.

Now as to the observations made in the County of Galway.

The rainfall at Ballinasloe was 1·23 in. The rain began at 12.30 p.m., and it is not recorded at what time it ended. The wind was from the West, and was of moderate force.

The fall at Garbally Gardens, near Ballinasloe, was 1·03 in. The barometer fell very rapidly. On August 31st it was 29·20 ins., and on September 1st it was 28·75 ins. The temperature on that day was :—Highest 59°, lowest 50°. I find that the observer at Garbally does not follow the well-known meteorological rule which directs all observations to be made at 9 a.m. He states that he measured the rain at 6.30 p.m. on September 1st, and at 6.30 p.m. on the 2nd again, and found the gauge contained ·93 in. It is certain that part of this ·93 should be added to the observation made on the 1st at 6.30 p.m. He also states that the rain began on the 1st at 4.30 p.m., and that the amount recorded (1·03) fell in about an hour. I would put much more faith in the report of the observer at Ballinasloe, who is a civil engineer by profession. Garbally is quite close to Ballinasloe.

TABLE V.—ESTIMATED YIELD OF FRUIT CROPS IN 1889.

| Description of Crop. | England. | | | | | |
|---|---|---|---|---|---|---|
| | A. SW. | C. S. | D. Mid. | E. E. | F. NW. | I. NE. |
| Apples | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Pears | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Plums | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | .. |
| Raspberries | O. Av. | O. Av. | O. Av. | O. Av. | Av. | O. Av. |
| Currants | O. Av. | O. Av. | O. Av. | O. Av. | Av. | Av. |
| Gooseberries | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. |
| Strawberries | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. |

| Description of Crop. | Scotland. | | | Ireland. | British Isles. |
|---|---|---|---|---|---|
| | H. W. | J. E. | K. N. | B. and G. S & N. | |
| Apples | | U. Av. | | U. Av. | U. Av. |
| Pears | | U. Av. | | U. Av. | U. Av. |
| Plums | | O. Av. | | Av. | U. Av. |
| Raspberries | | O. Av. | | O. Av. | O. Av. |
| Currants | | O. Av. | | O. Av. | O. Av. |
| Gooseberries | | O. Av. | | O. Av. | O. Av. |
| Strawberries | | Much O. Av. | | Much O. Av. | Much O. Av. |

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

23rd. Snowdrop in blossom. 31st. Celandine in bloom—earliest date for six years. *Buckhorn Weston* (C.). A great quantity of primroses in blossom, not only in sheltered nooks but in more exposed places. Thrushes have been singing all the month, and I have found two blackbirds' nests in process of building. Rooks, too, have begun to build. *Salisbury* (C.). Up to the end of the month, no frog spawn had been seen. 21st. No fertile flowers of the Hazel could be found. Catkins unusually small. Vegetation generally was, at this time, by no means remarkably forward. *Hodsock* (D.). At the end of the month a few snowdrops and aconites were in flower, also a few primroses. 27th. Both barren and fertile flowers of the Hazel in blossom.

FEBRUARY.—*Usk* (A.). Have noticed comparatively few fieldfares this year. *Pennington* (C.). Vegetation made scarcely any progress during this month. 9th. A pear in blossom—a solitary flower. 25th. Yew in blossom. *Macclesfield* (D.). 2nd. A change to colder weather. Many plants were killed—wallflowers, pansies, &c. 8th. Heavy snow storm, the branches of many trees and shrubs broken by the weight of snow. Plum trees and Scotch firs suffered most. *Hodsock* (D.). Snowdrops in full flower. *Tacolneston* (E.). 2nd. Pyrus Japonica, with a good many flowers open, on a sheltered south wall. These blossoms were, however, destroyed by frost during the second week.

## *The Spring of 1889.*

This was in all districts a more or less cold spring, with a heavy rainfall and a considerable amount of bright sunshine. Early in March there occurred in most localities an unusually severe frost. Indeed, the weather was then in many places colder than at any time during the three previous winter months. The only districts which appear to have escaped this frost

were Ireland South and England South-west and West. During April no damaging cold was recorded, but throughout a great part of the month low temperatures prevailed almost everywhere. The absence of night frosts in May was the most marked characteristic of that month, and as affecting vegetable growth the most noteworthy feature of the year. Until the end of April vegetation was almost everywhere very backward, but the warm showery weather which May brought with it wrought a complete change, and from this time a very rapid advance was made. The foliage of trees at the close of the season was remarkably luxuriant. Several observers, both in the warmer as well as the colder districts, mention the absence of bloom on the beech and ash. On the other hand, the blossom on such fruit trees as apples, pears, cherries, &c., proved unusually abundant. Nevertheless, on close examination these blossoms were found to be in many cases imperfectly formed, while the young leaves suffered greatly from the ravages of caterpillars and aphis. As regards birds, the spring migrants seem everywhere to have been less numerous than usual, and to have been, moreover, late in making their appearance.

*Observers' Notes.*

MARCH.—*Babbacombe* (A.). 27th. Hawthorn in leaf. *Usk* (A.). Vegetation generally stationary after about the 20th, owing to cold weather. *Wells* (A.). Vegetation backward, not so much from prolonged or severe cold as from absence of sunshine and cold dampness. *Pennington* (C.). Spring sowing on heavy soil very backward by end of month, owing to frequent rains. 16th. Darwinii Berberis in flower. 26th. Missel Thrush's nest, with two eggs in it. 29th. Saw one Peacock, three Brimstone and two small Tortoiseshell butterflies. *Salisbury* (C.). 22nd. Peach in blossom. 31st. The first water spider seen. *Ealing* (C.). The garden spring flowers are backward. Crocuses were not abundant till the 13th. *Northampton* (D.). There having been but very little sunshine and not many warm days, vegetation was very backward at the end of the month. *Hodsock* (D.). 19th. Eggs in Thrush's nest. 29th. A few green leaves on Hawthorn in sheltered places.

*The Summer of 1889.*

The summer of the past year was, on the whole, a cold, wet and sunless one. Throughout June the weather continued changeable, but for the most part warm and summer like. The record of sunshine was, moreover, large, while very little rain fell after the first week. On the other hand, during nearly the whole of July and August the temperature ruled persistently low, and there was comparatively little bright sunshine. The total rainfall in these two months was not much in excess of the average; but then, again, there occurred very few fine days. During June and the first half of July vegetation generally was very forward, and the hedgerows, fields and woods were even gayer than is usual at this season with wild flowers. The crop of hay proved an abundant one, and nearly the whole of it was harvested early and in splendid condition. The drought which prevailed in most districts during the latter half of June and the early part of July was at the end of this period becoming much felt, so that the moister and cooler weather which followed was at first greatly welcomed. Unfortunately, however, for the cereals, and more particularly for the wheat crop, these cooler conditions

TABLE V.—ESTIMATED YIELD OF FRUIT CROPS IN 1889.

| Description of Crop. | England. | | | | | |
|---|---|---|---|---|---|---|
| | A. SW. | C. S. | D. Mid. | E. E. | F. NW. | I. NE. |
| Apples | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Pears | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. |
| Plums | U. Av. | U. Av. | U. Av. | U. Av. | U. Av. | .. |
| Raspberries | O. Av. | O. Av. | O. Av. | O. Av. | Av. | O. Av. |
| Currants | O. Av. | O. Av. | O. Av. | O. Av. | Av. | Av. |
| Gooseberries | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. | O. Av. |
| Strawberries | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. | Much O. Av. |

| Description of Crop. | Scotland. | | | Ireland. | British Isles. |
|---|---|---|---|---|---|
| | H. W. | J. E. | K. N. | B. and G. S & N. | |
| Apples | | U. Av. | | U. Av. | U. Av. |
| Pears | | U. Av. | | U. Av. | U. Av. |
| Plums | | O. Av. | | Av. | U. Av. |
| Raspberries | | O. Av. | | O. Av. | O. Av. |
| Currants | | O. Av. | | O. Av. | O. Av. |
| Gooseberries | | O. Av. | | O. Av. | O. Av. |
| Strawberries | | Much O. Av. | | Much O. Av. | Much O. Av. |

O. Over. U. Under. Av. Average.

This Table has been compiled from Returns sent in to the *Gardeners' Chronicle* and the *Garden* during the Autumn.

23rd. Snowdrop in blossom. 31st. Celandine in bloom—earliest date for six years. *Buckhorn Weston* (C.). A great quantity of primroses in blossom, not only in sheltered nooks but in more exposed places. Thrushes have been singing all the month, and I have found two blackbirds' nests in process of building. Rooks, too, have begun to build. *Salisbury* (C.). Up to the end of the month, no frog spawn had been seen. 21st. No fertile flowers of the Hazel could be found. Catkins unusually small. Vegetation generally was, at this time, by no means remarkably forward. *Hodsock* (D.). At the end of the month a few snowdrops and aconites were in flower, also a few primroses. 27th. Both barren and fertile flowers of the Hazel in blossom.

FEBRUARY.—*Usk* (A.). Have noticed comparatively few fieldfares this year. *Pennington* (C.). Vegetation made scarcely any progress during this month. 9th. A pear in blossom—a solitary flower. 25th. Yew in blossom. *Macclesfield* (D.). 2nd. A change to colder weather. Many plants were killed—wallflowers, pansies, &c. 8th. Heavy snow storm, the branches of many trees and shrubs broken by the weight of snow. Plum trees and Scotch firs suffered most. *Hodsock* (D.). Snowdrops in full flower. *Tacolneston* (E.). 2nd. Pyrus Japonica, with a good many flowers open, on a sheltered south wall. These blossoms were, however, destroyed by frost during the second week.

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Dickson (6 pp.). This is a collection of local weather sayings current among fishermen, which the author has collected while inspecting the Fishery barometers of the Meteorological Council.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. September to December 1889. 4to.

Contains :—Beiträge zur arktischen Meteorologie, von Dr. J. Hann (9 pp.). This is a summary of Parts IV. and V. of the *Contributions to our Knowledge of the Meteorology of the Arctic Regions*, published by the Meteorological Office. Dr. Hann speaks in high terms of the work of Mr. Strachan, and expresses his surprise that the work has not attracted more attention in England.—Der Krakatau-Ausbruch und seine Folge-Erscheinungen, von Dr. J. M. Pernter (38 pp.). This is a summary of the Krakatoa Report of the Royal Society, and deals with the geological and optical sections, and those on the sound and air and sea-waves. —Die wissenschaftlichen Erhebungen zur Wasserkatastrophe in der sächsischen Oberlausitz am 18 Mai 1887, von Dr. O. Birkner (7 pp. and plate). The author attributes the flood to the contour of the country, which caused a certain thundercloud to hang about the particular valleys and cause excessive rainfall of about six inches in the 24 hours. The destructive action of the water was aggravated by the fact of the country having been cleared of forest. Dr. Birkner recommends the inhabitants of the district which has suffered from floods to plant trees extensively, and especially to encourage growth of underwood on the sides of brooks.—Einige Anomalien in den Winden des nördlichen Indiens und ihre Beziehung zur Druckvertheilung, nach S. A. Hill (16 pp. and 2 plates). This is an abstract of Mr. Hill's paper in the *Philosophical Transactions*.—Zur Theorie des Bishop'schen Ringes, von Dr. J. M. Pernter (8 pp.). This is a criticism, *inter alia*, of the varying results from the diameter of the water particles producing Bishop's ring given respectively by Flögel, Forel, and Archibald; and the paper concludes with the hope that a set of measurements of solar and lunar coronæ will be undertaken, as our knowledge of the condition of the water suspended in the air is still very defective.—Wolkenformen und Wolkenbilder, von Prof. H. H. Hildebrandsson (7 pp.). This is a reproduction of the author's paper before the Congress in Paris, and concludes with a notice of the new Cloud Atlas.

QUEENSLAND METEOROLOGICAL REPORT FOR 1887. BY CLEMENT L. WRAGGE, Government Meteorologist. 4to. 1889. 129 pp. and numerous plates.

This being the first Annual Report of the Meteorological Branch of the Post and Telegraph Department, Mr. Wragge gives a full account of the organisation of the system and details *in extenso* the steps taken to prepare rules, inspect stations, &c. The stations are equipped in accordance with the recommendations of the Royal Meteorological Society.

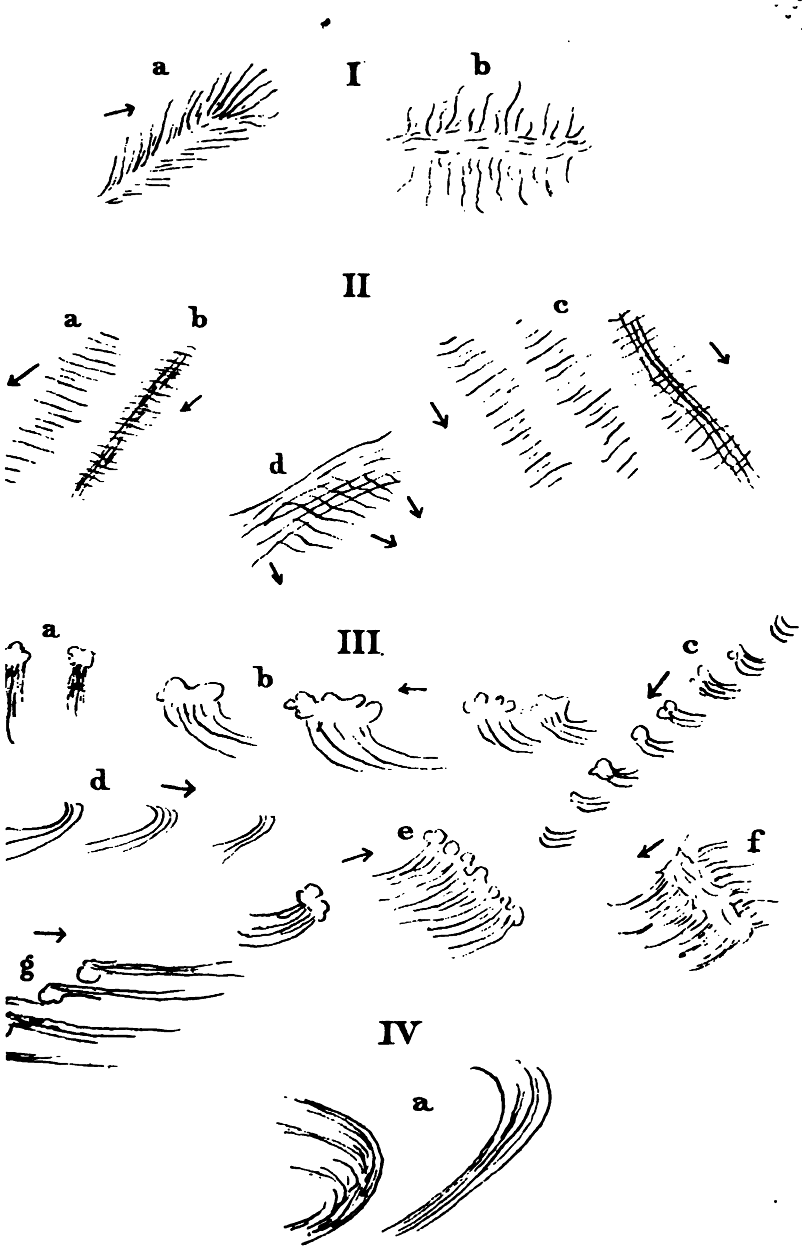
SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. October to December 1889. 8vo.

The principal contents are : The determination of the amount of rainfall, by Prof. Cleveland Abbe (6 pp.). This paper was read at the British Association meeting at Newcastle-on-Tyne.—Autumn Congresses (13 pp.). This is a brief summary of the meteorological reports and papers read at the recent meetings of the British Association, the Congrès International Météorologique, the Sanitary Institute, and the Congrès International d'Hydrologie et de Climatologie.—The floating island in Lake Derwentwater, by Prof. R. Meldola, F.R.S. (3 pp.).—On the black bulb thermometer *in vacuo*, by Prof. H. McLeod, F.R.S. (2 pp.).

THE OCEAN OF AIR. METEOROLOGY FOR BEGINNERS. By AGNES GIBERNE. With a Preface by the Rev. C. Pritchard, D.D., F.R.S. 8vo. 1890. 340 pp.

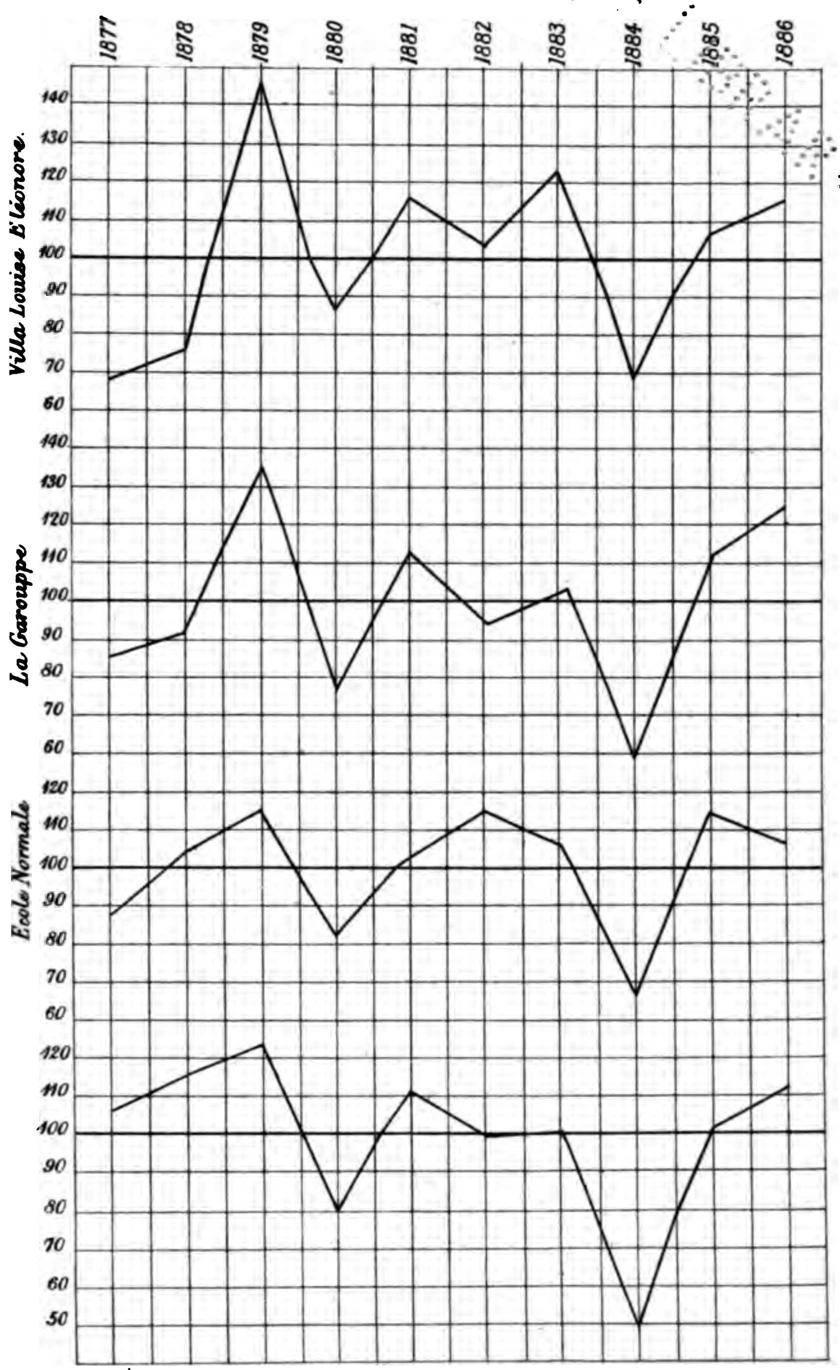
This is a very pleasantly written book dealing in an elementary manner with the Atmosphere, and is, in fact, as stated on the title page, "Meteorology for Beginners." The work is divided into 8 parts, which treat of the uses, gases, vapours, movements, disturbances, forces of, and life in, the air-ocean. The value of the book is increased by 16 plates engraved from instantaneous photographs.

# CIRRUS FORMATION.

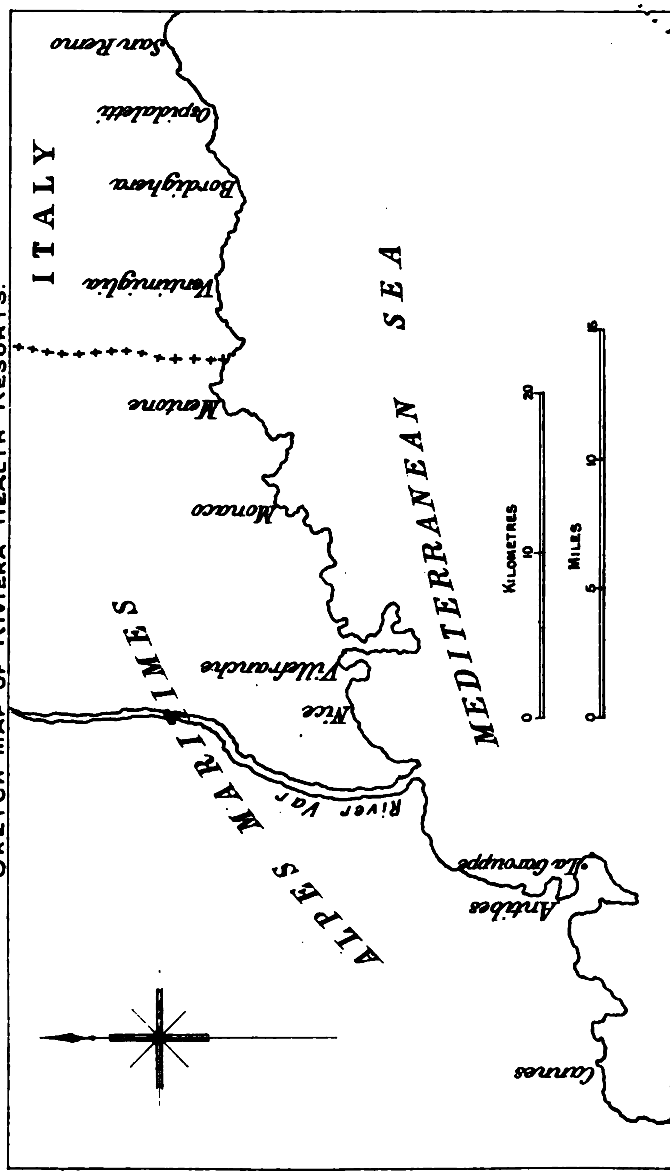



Malby & Sons, Lith.

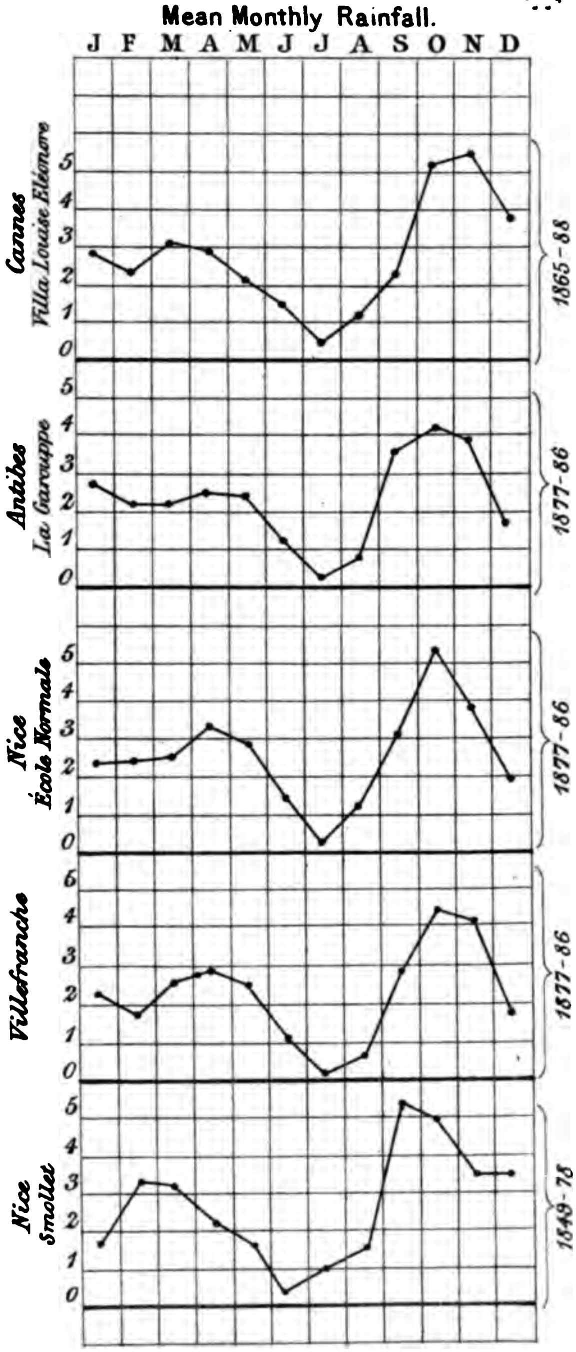
Relation of Total fall of Rain in each Year
to the mean 1877-86.



SKETCH MAP OF RIVIERA HEALTH RESORTS.



Mean Monthly Rainfall.



// QUARTERLY JOURNAL

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# ON ATMOSPHERIC DUST.

## An Address delivered to the Royal Meteorological Society, January 15th, 1890.

BY WILLIAM MARCET, M.D., F.R.S., PRESIDENT.

THE infinitely small particles of matter we call *dust*, though possessed of a form and structure which escape the naked eye, play, as you are doubtless aware, important parts in the phenomena of nature. A certain kind of dust has the power of decomposing organic bodies, and bringing about in them definite changes known as putrefaction, while other kinds exert a baneful influence on health and act as sources of infectious diseases. Again, from its lightness and extreme mobility, dust is a means of scattering solid matter over the earth. It will float in the atmosphere as mud does in water, and blown by the wind, may perhaps travel thousands of miles before again alighting on the earth. Thus Ehrenberg, in 1828, detected in the air of Berlin the presence of organisms belonging to African regions, and he found in the air of Portugal fragments of *infusoriæ* from the steppes of America. The smoke of the burning of Chicago was, according to Mr. Clarence King (Director of the United States Geological Survey), seen on the Pacific coast.

Dust is concerned in many interesting meteorological phenomena, such as

fogs, as it is generally admitted that fogs are due to the deposit of moisture on atmospheric motes. Again, the scattering of light depends on the presence of dust, and you may remember my showing you on a former occasion the beautiful experiment of Tyndall's, illustrating the disappearance of a ray of light when made to travel through a glass receiver free from dust, and its re-appearance as soon as dust was admitted into the vessel. There is no atmosphere without dust, although the amount varies largely, from the summit of the highest mountain where the least is found, to the low plains, at the seaside level, where it occurs in the largest quantities.

The origin of dust may be looked upon, without exaggeration, as universal. Trees shed their bark and leaves, which in dry weather are powdered and carried about by ever varying currents of air, plants dry up and crumble into dust, the skin of man and animal is constantly shedding a dusty material of a scaly form. The ground in dry weather, high roads under a midsummer's sun, emit clouds of dust consisting of very fine particles of earth. The fine river and desert sand, a species of dust, is silica ground down into a fine powder under the action of water.

If the vegetable and mineral world crumbles into *dust*, on the other hand it is highly probable that dust was the original state of matter before the earth and heavenly bodies were formed; but here we enter the region of theory and probabilities. In a science like meteorology, where a wide door is open to speculation, we should avoid as much as possible stepping out of the track of known facts; still there is a limit to physical observation, and in some cases we can do no more than glance into the possible or probable source of natural phenomena. Are we on this account to give up inquiring for *causes*? This question I shall beg to leave you to decide, but where we have such an experienced authority as Norman Lockyer, I think the weight attached to possibilities and theories is sufficiently great to warrant my drawing your attention for a few moments to the probable origin of the stars and of our earth.

I daresay many of you have read the interesting article in the *Nineteenth Century* of November last, by Norman Lockyer, and entitled "The History of a Star." The author proposes to clear in our imagination a limited part of space, and then set possible causes to work; that dark void will sooner or later be filled with some form of matter so fine that it is impossible to give it a chemical name, but the matter will eventually condense into a kind of dust mixed with hydrogen gas, and will constitute what are called *nebulæ*. These nebulæ are found by spectrum analysis to be made up of known substances, which are magnesium, carbon, oxygen, iron, silicon, and sulphur. Fortunately for persons interested in such inquiries, this dust comes down to us in a tangible form. Not only have we dust shed from the sky on the earth, but large masses, magnificent specimens of meteorites which have fallen from the heavens at different times, some of them weighing tons, may be submitted to examination. From the spectroscopic analysis of the dust of meteorites we find that in addition to hydrogen their chief constituents are magnesium, iron, silicon, oxygen and sulphur.

There are swarms of atoms of dust travelling through space, and their motion may be extremely rapid. We know, for instance, some stars to be moving so quickly that from Sir Robert Ball's calculations one among them would travel from London to Pekin in something like two minutes. From photographs taken of the stars and nebulæ, we are entitled to conclude that the swarms of dust meet and interlace with each other, becoming raised to a very high temperature by friction and collision, and giving rise to what look like stars. The light would last so long as the swarms collide, but would go out should the collision fail; or, again, such a source of supply of heat may be withdrawn by the complete passage of one stream of dust-swarms through another. We shall, therefore, have various bodies in the heavens, suddenly or gradually increasing or decreasing in brightness, quite irregularly, unlike those other bodies where we get a periodical variation in consequence of the revolution of one of them round the other. Hence, as Norman Lockyer expresses it clearly, "It cannot be too strongly insisted upon, that the chief among the new ideas introduced by the recent work is that a great many stars are not stars like the sun, but simply collections of meteorites, the particles of which may be probably thirty, forty, or fifty miles apart."

The swarms of dust referred to above undergo condensation by attraction or gravitation; they will become hotter and brighter as their volume decreases, and will pass from being nebulæ to being what we call true stars.

The author of the paper I am quoting from imagines such condensed masses of meteoric dust being pelted or bombarded by meteoric material, producing heat and light, which effect will continue so long as the pelting is kept up. To this circumstance is due the formation of stars like suns. Our earth originally belonged to that class of heavenly bodies, but from a subsequent process of cooling assumed its present character.

While apologising for this digression into extra-atmospheric dust, I shall propose to divide atmospheric dust into *organic*, or *combustible*, and *mineral*, or *incombustible*. The dust scattered everywhere in the atmosphere, and which is lighted up in a sunbeam, or in a ray from the electric lamp, is of an organic nature. It is seen to consist of countless motes, rising, falling, or gyrating, although it is impossible to follow any of them with the eye for longer than a fraction of a second. We conclude that their weight exceeds but very slightly that of the air, and, moreover, that the atmosphere is the seat of multitudes of minute currents, assuming all kinds of directions. Similar currents, though on a much larger scale, are also met with in the air. One day last June, from the top of Eiffel's Tower in Paris, I amused myself throwing an unfolded newspaper over the rail carried round the summit of the tower. At first it fell slowly, carried away by a light breeze, but presently it rose, and describing a curve, began again to fall. As it was vanishing from sight the paper appeared to me as if arrested now and then in its descent, perhaps undergoing again a slight upheaval. Here was indeed a gigantic mote floating in the atmosphere, and subject to the same physical laws, though on a larger scale, as those delicate filaments of dust we see dancing merrily in a sunbeam.

I recollect witnessing, at one of the Friday evening lectures of the Royal Institution in the year 1870, the following beautiful experiment of Dr. Tyndall, illustrative of the properties of atmospheric dust:—If we place the flame of a spirit lamp or a red-hot metal ball in the track of a beam of light, there will be seen masses of dark shadows resembling smoke emitted in all directions from the source of heat. At first sight this appears as if due to the dust particles being burnt into smoke; but by substituting for the spirit flame or red-hot metal ball an object heated to a temperature too low to burn the motes, the same appearance of smoke is observed, hence the phenomenon is not owing to the combustion of the dust. The explanation, however, is obvious. The source of heat, by warming the air in its contact and immediate proximity, made the air lighter and the motes relatively heavier, consequently they fell, and left spaces free from dust. These spaces in the track of the electric ray appeared dark, or looked as if full of a dense smoke, because, from the absence of dust, the light of the ray could no longer be scattered in them.

The motes were next examined by Tyndall, to determine whether they were organic or mineral. This was done by driving a slow current of air through a platinum tube heated to redness, and examining this air afterwards in a beam of light; it was then found to darken the ray, having lost the power of scattering light; therefore the dust had been destroyed or burnt by passing through the red hot platinum tube, clearly showing its organic nature.

We inhale into our lungs day and night this very finely-divided dust, and yet it produces no ill effect, no bronchial irritation. Tyndall has again shown by the analytical power of a ray of light what becomes of the motes we inhale.

Allow me to return to the experiment with the red-hot metal ball placed in the beam of the electric light. Should a person breathe on the heated ball, the dark smoke hovering around it will at first disappear, but it will reappear in the last portions of the air expired. What does this mean? It means that the first portions of air expired from the lungs contain the atmospheric motes inhaled, but that the last portions, after reaching the deepest recesses in the organs of respiration, have deposited there the dust they contained.

It is difficult to say how much of the dust present in the air may become a source of disease, and how much is innocuous. Many of the motes belong to the class of *micro-organisms*, and the experiment to which we have just referred shows how easily these micro-organisms, or sources of infectious diseases, can reach the lungs and do mischief if they should find a condition of the body upon which they are able to thrive and reproduce themselves. Atmospheric motes, although it has been shown that they are really deposited in the respiratory organs, do not accumulate in the lungs and air passages, but undergo decomposition and disappear in the circulation. Smoke, which is finely-divided coal dust, is clearly subjected to such a destructive process; otherwise the smoky atmosphere of many of our towns would soon prove fatal, and tobacco smoke would leave a deposit interfering seriously with the phenomena of respiration after a very short time.

Dust, however, in its physical aspect is far from being always innocuous, and, as you are aware, many trades are liable to suffer from it. The cutting of chaff, for horses' food, is one of the most pernicious occupations, as it generates clouds of dust of an essentially penetrating character. Those engaged in needle manufactures and steel grinders suffer much from the dust of metallic particles. Stone cutters, and workmen in plaster of Paris, coal heavers, cotton and hemp spinners are also engaged in trades injurious to health because of the dust these men unavoidably work in. Those engaged in cigar and rope manufactures, or in flour mills, hat and carpet manufacturers, are also liable to suffer for the same reason. A number of methods have been adopted, more or less successfully, to rid these trades of the danger due to the presence of dust. I shall not detain you on this subject, which would carry me too far, but merely bring to your notice the fact I observed many years ago, that charcoal has the power of retaining dust in a remarkable degree. I have had charcoal respirators made of such a form as to cover both the mouth and nose, and containing about ½ inch thick of charcoal in a granular state. I could breathe through such a respirator in the thickest cloud of dust made by chaff cutting without being conscious of inhaling any of the dust.

The subject of micro-organisms belongs to the science known as micro-biology. As meteorologists we are chiefly concerned with their distribution in the atmosphere. Micro-organisms are dust-like particles capable of cultivation or reproduction in certain media and at certain temperatures. If a particle of matter known to contain micro-organisms, also called *bacilli*, be placed on a clear surface of gelatine and maintained at a temperature favourable to their development, in a short time the gelatine will be found to contain a colony of those same *bacilli*. A fact so often stated as to become a medical truism is that there can be no infectious disease without the presence of the micro-organism special to that disease. Open cesspools, putrid meat or vegetable matter, accumulations of refuse have no ill effects on health unless the micro-organism of a certain disease, as those of typhoid fever or cholera, be present. On such foul decomposing matters these organisms thrive. They are reproduced with great activity, and become virulent in their effects.

Micro-organisms are scattered everywhere in the atmosphere. Dr. Miquel, at the Montsouris Observatory at Paris, has made an extensive inquiry into their distribution in air and water. In this country Dr. Percy Frankland has, with praiseworthy labour and perseverance, investigated the subject of micro-organisms, and ascertained their number in various localities. The result of his inquiry is that in cold weather, especially when the ground is covered with snow, the number of organisms in the air is very much reduced, and presents a very striking contrast with that found in warmer weather. The experiments made on a March day show that during cold and dry weather, with a strong East wind blowing over London, a large number of micro-organisms may still be present in the air. It is particularly noticeable that even after an exceedingly heavy rain, and within a few hours afterwards, the number of micro-organisms in the air should be as abundant as usual.

Taking an average of the experiments made on the roof of the Science Schools of the South Kensington Museum, the mean number of organisms found in 10 litres of air amounted to 85, while an average of 279 fell on one square foot in one minute. Other experiments made near Reigate and in the vicinity of Norwich present a marked contrast with those undertaken in the South Kensington Museum. There was a remarkable freedom from micro-organisms of the air collected on the heath near Norwich during comparatively warm April weather, when the ground was dry. The air in gardens at Norwich and Reigate was richer in micro-organisms than that of the open country. Again, the number of organisms found in the air of Kensington Gardens, Hyde Park, and Primrose Hill was less than in that taken from the roof at South Kensington, but greater than in the country.

Experiments made in enclosed places, where there is little or no aerial commotion, show the number of suspended organisms to be very moderate, but as soon as any disturbance in the air occurs, from draughts or people moving about, the number rapidly increases and may become very great. Experiments made in a railway carriage afford a striking example of the enormous number of micro-organisms which become suspended in the air when many persons are brought together.

Micro-organisms being slightly heavier than air, have an invariable tendency to fall, and on that account frequently collect on the surface of water; hence rivers, lakes and ponds are constantly being thus contaminated. Micro-organisms in very pure water are not readily disposed to multiply, but traces of decomposing organic matter will induce their reproduction. One remarkable case occurs to me illustrating this fact. In 1884 a severe epidemic of typhoid fever broke out in the City of Geneva. The water of the lake in the harbour, which is surrounded by houses on three sides, was then examined by a distinguished micro-biologist, M. Fol, who discovered it to be full of micro-organisms; the water supplied to the town for drinking purposes was taken from the River Rhône immediately as it flowed out of the harbour. The inquiry was pursued further, and it was found that just outside the harbour, on the surface of the water, there were still a number of micro-organisms, though less than in the harbour; but a few feet below the surface, say 3 or 4 feet, they had greatly diminished in number, indeed to such an extent that there were very few present. The obvious remedy was at once carried out. A wooden aqueduct was constructed, opening into the lake about 150 yards outside the harbour, and some 3 or 4 feet under the surface. As stated by Dr. Dunant, a Geneva physician who has given a very interesting account of this epidemic,[1] eighteen days after the source of the water-supply had thus been altered, a marked decline took place in the epidemic, and it was clearly being mastered. A similar epidemic, due to a like cause, occurred about the same time at Zurich.

There is one point connected with the properties of dust of organic origin

[1] Epidémie de fièvre Typhoide à Genève en 1884, par P. L. Dunant, *Revue Médicale de la Suisse Romand*, 1887.

which I think cannot fail to be of interest. I mean its inflammability, and its liability to explode when mixed with air. By *explosion* is meant that the propagation of flame by a very finely-divided material such as coal dust, mixed in due proportion with air, may proceed with a rapidity approaching the transmission of explosion by a gaseous mixture.

An interesting lecture was delivered on this subject at the Royal Institution, in April 1882, by Sir Frederick Abel, entitled "Some of the dangerous properties of dust." The lecturer refers to instances of explosions in flour-mills, due in all probability to a spark from the grinding mill-stones, occurring in consequence of a deficient supply of grain to the stones.

Messrs. Franklin and Macadam, who investigated the subject, found that accidents of this nature were of frequent occurrence. In May 1878 a flour-mill explosion, quite unparalleled for its destructive effects, occurred at Mineapolis, Minnesota. Eighteen lives were lost, and six distinct corn mills were destroyed. Persons who were in proximity to the scene of the calamity heard a succession of sharp hissing sounds, doubtless caused by the very rapid spread of flame through the dust-laden air of the passages inside the mill. The nearest mill to that first fired was 25 feet distance, and exploded as soon as the flames burst through the first mill. The explosion of the third mill, 25 feet from the second, followed almost immediately; and the other three mills, about 150 feet distance in another direction, were at once fired. The fire was attributed to a spark from friction of the mill-stones.

Coal dust in coal mines is a cause of accident from explosions, which has been closely investigated in this country, in Germany and other mining districts. Sir Frederick Abel has given this subject especial attention, and brings it prominently forward in his valuable and exhaustive paper on "Accidents in Mines," read at the Institution of Civil Engineers in 1888. Some mines are, of course, more dusty than others, and coal dusts are not all equally inflammable. That which is deposited upon the sides, top timbers, and ledges in a dry, dusty mine-way, is much finer and more inflammable than the coarser dust which covers the floors. The lecture I have referred to alludes to the case of a considerable quantity of coal dust accidentally thrown over some screens at a pit-mouth bursting into flame as the dust cloud came into contact with a neighbouring fire, and burning a man very severely. There appears good ground for believing that fire may travel to a considerable extent through the workings of a mine from the ignition of coal dust, as will be seen in the following account, extracted from Messrs. W. N. and J. B. Atkinson's book on *Explosions in Mines*:—"An appalling accident happened at the Seaham Colliery, in the County of Durham, on the 8th September, 1880, at 2.20 a.m., causing the death of 24 men. An explosion occurred in the mine, and a loud report was heard at the surface, accompanied with a cloud of dust from the shaft, but no fire was seen. Owing to damage to the shaft it was more than twelve hours before a descent could be effected, and then a scene of destruction was witnessed by the explorers. Doors and air-crossings destroyed; tubs broken to pieces, and hurled one over the other; timber blown out, attended with heavy falls from the roof; and the bodies of men

and horses in many cases terribly mutilated. The explosion was found to have extended over roads of an aggregate length of about 7,500 yards, the greatest distance between the extreme points reached being about 3,800 yards."

When discussing the cause of this terrible accident Messrs. Atkinson remark that it was apparently impossible to account for the effects of the explosion on the assumption that it was due to fire-damp, as the presence of fire-damp was most unlikely to occur at any part at which the explosion could have happened; and, therefore, attention must be turned to coal dust. There was coal dust on all the roads traversed by the explosion, and there was coal dust at the supposed point of origin. These facts are of striking significance. After the explosion, all parts of the mine in which its effects could be traced were covered on the bottom and on flat surfaces with a coating of fine dust, which, when examined under the microscope, appeared to have been acted on by great heat. This fine dust covered the surface for a depth of from ⅛ to ½ an inch and under. Dust of this kind was entirely absent on those roads over which the explosion had not extended. With reference to the original ignition, a shot had been fired apparently simultaneously with the explosion. The road at the place was of stone, and would probably be coated with the finest coal dust; and, moreover, just above the spot where the fatal shot was fired were large balks of timber, on which dust had plentifully collected. The shock caused by the explosion would throw the dust into the air, and the flame would set fire to it. Thus initiated the flame would extend through all the roads on which there was an uninterrupted supply of coal dust to support it.

The second part of this Address relates to inorganic, or mineral dust. When on the Peak of Tenerife in 1878, engaged in a pursuit mostly of a physiological kind, I had occasion to use a very delicate chemical balance. My object was to determine the amount of aqueous vapour given out of the lungs while in the shallow crater at the summit of the Peak, 12,200 feet above the sea. The heat was intense, as the sun shed its nearly vertical rays at midday on the fine white volcanic sand spread over the floor of the crater. At various places rocks projected, covered here and there with crystals of sulphur, and so hot that the hand could scarcely bear contact with them. Anticipating some difficulty in the use of the balance from the action of the wind, I had brought up with me a hamper and a blanket. After placing the hamper sideways, with the lid off, I proceeded, though not without some little trouble, to dispose the balance satisfactorily inside the basket; then, having thrown the blanket over the hamper, I stretched out at full length on the burning sand, nestling under the blanket, much as a photographer would cover himself and camera with a dark cloth. On trying to use the balance, it refused to act; its beam would not oscillate. A careful examination showed the instrument to be apparently in perfect order, when it occurred to me to wipe the knife edges at the points of suspension of the beam and pans. The balance then worked quite well, though, but for a few minutes only, again most provokingly declining to

oscillate; indeed, it was only by constant wiping of the knife edges that I succeeded with my experiment. The cause of my trouble was clearly the presence of very fine mineral dust in the air, of which my senses were utterly unconscious. Hence it is that extremely fine particles of mineral dust may exist in the atmosphere, escaping detection by our senses, and such an occurrence is probably more frequent than is generally thought.

Professor Piazzi Smyth, while on the Peak of Tenerife, witnessed strata of dust rising to a height of nearly a mile, reaching out to the horizon in every direction, and so dense as frequently to hide neighbouring hills. The Report of the Krakatoa Committee of the Royal Society contains the following interesting account, p. 421 (Mr. Archibald's contribution to the report):—In 1881 Professor S. P. Langley ascended Mount Whitney, in Southern California, with an expedition from the Alleghany Observatory; at an altitude of 15,000 feet his view extended over one of the most barren regions in the world. Immediately at the foot of the mountain was the *Inyo Desert*, and in the east a range of mountains parallel to the Sierra Nevadas, but only about 10,000 feet in height. From the valley the atmosphere had appeared beautifully clear; but, as stated in Professor Langley's own words, "from this aerial height we looked down upon what seemed a kind of level dust ocean, invisible from below, but whose depth was six or seven thousand feet, as the upper portion only of the opposite mountain range rose clearly out of it. The colour of the light reflected to us from this dust ocean was clearly red, and it stretched in every direction as far as the eye could reach, although there was no special wind or local cause for it. It was evidently like the dust seen in mid-ocean from the Peak of Tenerife—something present all the time, and a permanent ingredient of the earthy atmosphere."

*Dust Storms.*—These storms, as suggested by Dr. Henry Cook, (from whose paper to the *Quarterly Journal of the Royal Meteorological Society* in 1880, I am now quoting,) may be considered under three heads, according to their intensity—atmospheric dust, dust columns, and dust storms. Dr. Cook, alluding to occurrences in India, observes that there are some days on which, however hard and violently the wind may blow, little or no dust accompanies it; while on others every little puff of air or current of wind forms or carries with it clouds of dust. If the wind which raises the dust is strong, nothing will be visible at the distance of a few yards, the sun at noon being obscured. The dust penetrates everywhere, and cannot be excluded from houses, boxes, or even watches, however carefully closed. The individual particles of sand appear to be in such an electrical condition that they are ever ready to repel each other, and are consequently disturbed from their position and carried up into the air.

Dust columns are considered by Dr. Cook as due to electrical causes. On calm, quiet days, when hardly a breath of air is stirring, and the sun pours down its heated rays with full force, little eddies arise in the atmosphere near the surface of the ground. These increase in force and diameter, catching up and whirling round bits of sticks, grass, dust, and lastly sand, until a column is formed of great height and considerable diameter, which usually,

after remaining stationary for some time, sweeps away across country at great speed. Ultimately it loses gradually the velocity of its circular movement and disappears. In the valley of Mingochar, which is only a few miles in width, and surrounded by high hills, Dr. Cook, on a day when not a breath of air stirred, counted upwards of twenty of these columns. They seldom changed their places, and when they did so moved but slowly across the level track. They never interfered with each other, and appeared to have an entirely independent existence.

Dr. Cook describes as follows a dust storm which took place at Jacobabad :—"The weather had been hot and oppressive, with little or no breeze, and a tendency for dust to accumulate in the atmosphere. On the evening of the storm heavy clouds gathered and covered the sky. About 9 p.m. the sky had cleared somewhat, and the moon shone. A breeze sprang up from the west, which increased and bore along with it light clouds of sand. About 9.30 p.m. the storm commenced in all its fury. Vast bodies of sand were drifted violently along. The stars and moon were totally obscured. It became pitch dark, and it was impossible to see the hand held close to the face. The wind blew furiously in gusts, and heaped the sand on the windward side of obstacles in its course. Lightning and thunder accompanied it, and were succeeded by heavy rain. The storm lasted about an hour, when the dust gradually subsided. The sky again became clear, and the moon shone brightly. The storm appeared to have entirely relieved the electrical condition of the atmosphere. A pleasant freshness followed, and the oppressive sensation before mentioned was no longer experienced. This, indeed, is the general effect of storms in Upper Scinde. The air is cooled, the atmosphere cleared, and the dusty condition of the atmosphere which usually precedes them for several days completely disappears."

In the case of a memorable sand-storm which occurred at Aden on July 16th, 1878, and recorded by Lieut. Herbert Russell, there was a remarkable play of light on the objects which remained within sight. The sudden darkness from the storm gave a peculiar and ghastly tint to the white sand and neighbouring plain, while the curling masses of sand drifted before the gale, resembling a dark yellow smoke. The varied lights, quickly changing, were curious and most grand ; the sea a clear green, and Slave Island and Shum-Shum, usually of an arid brown colour, became of an ashy white.

In a dust storm I experienced myself at Luxor, on the Nile, the suffocating effect of the sand as it drove into the lungs and air passages was very trying. People rushed to the adjacent river-side, where some relief was found.

A book on *Whirlwinds and Dust Storms in India*, by P. L. H. Baddeley, Surgeon Bengal Army, 1860, gives some interesting information on the electrical character of dust storms and dust pillars. When at Lahore in 1847, this gentleman was desirous of experimenting on the electrical state of the atmosphere in a dust storm, and with this object he projected into the air, on the top of his house, an insulated copper wire fixed to a bamboo, the wire was brought through the roof into his room, and connected with a gold-leaf

electrometer, a detached wire communicating with the earth. A day or two after, during the passage of a small dust storm, he observed the passage of vivid sparks from one wire to the other, of course, strongly affecting the electrometer. He subsequently witnessed at least sixty dust storms of various sizes, all presenting the same kind of phenomena.

*Volcanic Dust.*—This dust consists mainly of powdered vitrified substances, produced by the action of intense heat. It is interesting in many respects. The so-called ashes or scoriæ shot out in a volcanic eruption are mostly pounded pumice, but they also originate from stones and fragments of rocks which, striking against each other, are reduced into powder or dust. Volcanic dust has a whitish-grey colour, and is sometimes nearly quite white. Thus it is that, in summer, the terminal cone of the Peak of Tenerife appears from a distance as if covered with snow; but at that season of the year there is no snow on the mountain; the white cap on the Peak is entirely due to pumice ejected centuries ago. It is probably to this circumstance that the island and Peak owe their name, as in the Guanch language the words *Tener Ifa* mean *white mountain.*

The friction caused by volcanic stones and rocks as they are crushed in their collision develops a mass of electricity, which shows itself in brilliant displays of branch lightning darting from the edges of the dense ascending column. During the great eruption of Vesuvius, in 1822, they were continually visible, and added much to the grandeur of the spectacle. It not infrequently happens that dust emitted from Vesuvius falls into the streets of Naples; but this is nothing in comparison with the mass of finely-powdered material which covered and buried the towns of Pompeii, Herculaneum, and Stabiæ in the year 79 A.D.

On this occasion, according to the younger Pliny, total darkness from the clouds of volcanic ashes continued for three days, during which time ashes fell like a mantle of snow all over the surrounding country. When the darkness cleared away the calamity was revealed in all its awful extent, the three towns having disappeared under the showers of dust.

The eruption of Krakatoa, a mountain situated on an island in the Straits of Sunda, exceeded, in all probability, in its deadly effects, and as a wonderful phenomenon of nature, the outburst of Vesuvius in the year 79. The Krakatoa Committee of the Royal Society have collected and published in their interesting Report particulars of that memorable eruption, all of them thoroughly authenticated and reliable. The following is extracted from a communication to the report by Professor Judd:—On the 26th August, 1883, it was evident that the long continued moderate eruptions of Krakatoa had passed into the paroxismal stage. That day, about 1 p.m., the detonations caused by the explosive action attained such a violence as to be heard at Batavia and Buitenzorg, about 100 English miles away. At 2 p.m. Captain Thompson, of the *Medea*, then sailing at a point 76 miles ENE of Krakatoa, saw a black mass like smoke in clouds rising to an altitude which has been estimated at no less than seventeen miles (nearly six times the height of Mont Blanc).

If this surmise be correct, some idea of the violence of the outburst can be formed from the fact that during the eruption of Vesuvius in 1872 the column of steam and dust was propelled to a height of from 4 to 5 miles only.

At 8 p.m. the explosions were loud enough to be heard 150 miles away. At Batavia and Buitenzorg the noise is described as being like the discharge of artillery close at hand. Windows rattled, pictures shook, but there was nothing of the nature of earthquake shocks—only strong air vibrations.

Captain Woolridge, of the *Sir R. Sale*, viewing the volcano at sunset on the 26th, describes the sky as presenting a most terrible appearance, the dense mass of cloud of a murky tinge being rent with fierce flashes of lightning. At 7 p.m., when from the vapour and dust clouds intense darkness prevailed, the whole scene was lighted up by electrical discharges, and at one time the cloud above the mountain presented the appearance of an immense pine tree, with the stem and branches formed of volcanic lightning. The air was loaded with excessively fine ashes, and there was a strong sulphurous smell. The steamer *G. G. Loudon*, within 20 or 30 miles of the eruption, passed through a rain of ashes and small bits of stone.

Captain Watson, of the ship *Charles Bal*, at a spot about a dozen miles off the island, records the phenomena of chains of fire appearing to ascend between the volcano and the sky, while on the south side there seemed to be a "continual roll of balls of white fire." These appearances were doubtless caused by the discharge of white-hot fragments of lava rolling down the sides of the mountain. From midnight till 4 a.m. explosions continually took place, the sky one second being intense blackness, the next a blaze of fire.

All the eye-witnesses agree as to the splendour of the electrical phenomena. Captain Woolridge, viewing the eruption from a distance of 40 miles, speaks of the great vapour cloud resembling an immense wall, with outbursts of fork lightning, like large luminous serpents rushing through the air. After sunset, this dark wall assumed the appearance of a blood-red curtain, with the edges of all shades of yellow—the whole of a murky tinge, and attended with fierce flashes of lightning. It was reported from the *G. G. Loudon* that lightning struck the mast-head conductor five or six times, and that the mud-rain which covered the masts, rigging, and decks was phosphorescent. The rigging presented the appearance of St. Elmo's fire, which the native sailors were busily engaged putting out with their hands, alleging that, if any portion found their way below, a hole would burst in the ship; not that they feared the ship taking fire, but they thought that the light was the work of evil spirits, and that if it penetrated to the hold the evil spirits would triumph in their design to scuttle the ship.

By these grand explosive outbursts the old crater of Krakatoa was completely eviscerated, and a cavity formed more than 1,000 feet in depth; while the solid materials thrown out from the crater were spread over the flanks of the volcano, forming considerable alterations in their forms.

The sea disturbance which accompanied the eruption of Krakatoa was carefully investigated by Captain Wharton, Hydrographer to the Admiralty:

—"The rush of the great sea wave over the land, caused by the violent abrasion in the crater, aided by the action on the water of enormous masses of fallen material, caused great destruction of life and property in the Straits of Sunda. By the inrush of these waves on land all vessels near the shore were stranded, the towns and villages near the coast devastated, two of the lighthouses were swept away, and the lives of 36,380 of the inhabitants sacrificed. It was estimated that the wave was about 50 feet in height when it broke on the shore."

On the morning of the 27th, between 10 and 11 a.m., three vessels at the eastern entrance of the Straits encountered the fall of mingled dust and water, which soon darkened the air, and covered their decks and sails with a thick coating of mud. Some of the pieces of pumice falling on the *Sir R. Sale* were said to have been of the size of a pumpkin. All day on the 27th the three vessels were beating about in darkness, pumice-dust falling upon them in such quantities as to employ the crew for hours in shovelling it from the decks and in beating it from the sails and rigging. At Batavia, 100 miles from Krakatoa, the sky was clear at 7 a.m., but at 11 a.m. there fell a regular dust-rain; at 11.20 complete darkness pervaded the city. The rain of dust continued till 1, and afterwards less heavily till 3 p.m.

The speed and distance attained by the pumice ejected from the volcano may be conceived from the fact stated in Mr. Archibald's contribution to the Report, that dust fell on the 8th of September more than 3,700 English miles from the seat of the eruption.

The great mass of the pumice thrown out during the eruption presented a dirty greyish-white tint, being very irregular in size. It was undoubtedly due to the collision of fragments of pumice as they were violently ejected from the crater; the noise they produced was even more striking than the sound of the explosion.

The dust ejected from Krakatoa did not all fall back at the same time upon the sea and earth; as the lighest portions of it formed haze, which was propagated mostly westwards. Mr. Archibald states in the Report that most observers agree in considering this haze as the proximate cause of the twilight glows, coloured suns and large coronæ, which were seen for a considerable time after the eruption. The haze was densest in the Indian Ocean and along the equatorial belt, and was often thick enough to hide the sun entirely when within a few degrees from the horizon.

And now, ladies and gentlemen, I must bring this Address to a conclusion, and thank you for having followed me over a long, dusty track. I hope I have succeeded in showing that infinitely small objects, no larger than particles of dust, act important parts in the physical phenomena of nature, just as small and apparently unimportant events occasionally lead to others of the greatest magnitude.

# REPORT OF THE COUNCIL

## *FOR THE YEAR 1889.*

THE Council have much pleasure in congratulating the Fellows on the generally prosperous state of the Society; the past year's work, though not in any respect exceptional, having been thoroughly successful. The total number of Fellows is 549, being an increase of 24 on the previous year; the finances are improving and the Library is overflowing. The routine of reducing and publishing the observations made at the Society's stations, and preparing and supervising the reports and papers read at the meetings, take much time, and in carrying on the work the Council have received considerable help from the various Committees, as well as from the members of the staff. The Committees and the Members thereof are as follows, viz.:—

GENERAL PURPOSES COMMITTEE.—The President, Secretaries, Foreign Secretary, Treasurer, Messrs. Bayard, Brewin, Ellis, Latham, and Williams.

EDITING COMMITTEE.—Messrs. Blanford, Inwards, and Scott.

STANDING REFEREE ON PAPERS.—Mr. Ellis.

ANNUAL EXHIBITION COMMITTEE.—The President, Secretaries, Messrs. Ellis, Scott, Strachan, and Whipple.

DECREASE IN WATER SUPPLY COMMITTEE.—The President, Messrs. Chatterton, Latham, and Symons; with Mr. Scott, representing the Meteorological Council.

WIND FORCE COMMITTEE.—The President, Secretaries, Messrs. Archibald, Chatterton, Dines, C. Harding, Laughton, Munro, Scott, and Toynbee; with Mr. Whipple, representing the Kew Committee.

THUNDERSTORM COMMITTEE.—The President, Secretaries, Messrs. Abercromby, Beaufort, Inwards, Scott, and Whipple.

LIBRARY CATALOGUE COMMITTEE.—Messrs. Eaton, Scott, and Symons.

The *Annual Exhibition of Instruments*, which was held on March 19th to 22nd, was attended by a large number of Fellows and visitors, and gave much satisfaction. It was held as usual in the rooms of the Institution of Civil Engineers, and the Catalogue contained a description of 71 different exhibits, arranged under the following divisions—1. Actinometers; 2. Solar Radiation Thermometers; 3. Sunshine Recorders; 4. New Instruments made since the last Exhibition; 5. Models; and 6. Photographs, Drawings, &c. The Council recommend to the Fellows the perusal of the catalogues of this and the previous Exhibitions, as containing valuable information in a condensed form.

*The Wind Force Committee* have had several meetings, and have also visited Hersham in Surrey, to witness the experiments made by Mr. Dines, with the assistance of Mr. Whipple and Mr. Munro. Reports were read at the meetings held in May and December and are printed in the *Quarterly Journal.* The experiments, as far as they have gone, are of considerable value, showing that the factor (3) of the Robinson's Anemometer (Kew pattern) is decidedly too high, also that no simple factor is of general applica-

bility. The best thanks of the Society are due to Mr. Dines for the great skill he has displayed in the inquiry, and the trouble and large amount of time he has devoted to the subject.

*Thunderstorm Observations and Discussions.*—In the early part of the year an extra assistant was engaged to tabulate the large mass of materials which the Society has collected respecting thunderstorms. Under Mr. Marriott's supervision he extracted all the reported dates of thunderstorms in England and Wales during the 17 years 1871-1887. The results were embodied in a paper, which was read at a meeting of the Society and printed in the *Journal.* This paper is to be followed by a careful discussion of the phenomena recorded during the thunderstorms of 1888-89, which, it is hoped, will soon be ready for reading at a meeting of the Society. Several new photographs of lightning flashes have been received during the year.

*The Inquiry respecting the Helm Wind* has for the present been discontinued, partly owing to the difficulty in getting the observers together before the phenomena have disappeared, and partly because there have been of late so few Helm Winds. Mr. Marriott read a paper as a Report on the subject, illustrated by a map and diagrams, which has been printed in the *Journal.* The Committee are of opinion that in some of the early accounts the intensity of the wind force was exaggerated.

*Inspection of Stations.*—The inspection this year comprised the stations in the South-west of England and in Wales, which were all found in a satisfactory condition. The alterations in the zero points of the thermometers were, however, more numerous than usual. The particulars will be found in Mr. Marriott's Report, Appendix II. (p. 93).

*Jordan Sunshine Recorder.*—As several of the Fellows and observers who use the Jordan Photographic Sunshine Recorder have measured the trace before fixing, while others have fixed the trace first, the Council have requested the observers who use this instrument always to fix the trace before measuring. By this means uniformity will be secured.

*International Congress of Hygiene.*—At the request of Sir Spencer Wells and other members of the Committee for organising the International Congress of Hygiene and Statistics to be held in London in 1891, the Council appointed Dr. Marcet and Dr. Tripe as delegates to represent the Society on the General Committee.

*Returns supplied to the Meteorological Council.*—For many years past the Society has supplied the Meteorological Council with copies of returns from a number of stations. Some slight modifications in the arrangement have recently been made, but they do not materially affect the amount of work, or the payment made to the Society by the Meteorological Office.

*Quarterly Journal and Meteorological Record.*—These publications have been continued as usual, and the former contains many interesting Addresses, Reports, and Papers. The *Record* has appeared with greater regularity, as the working staff has to a certain extent recovered from the difficulty arising in 1887 from the nearly simultaneous resignation of two of the computers who had been several years in the service of the Society, and fully under-

stood their work. Few changes have occurred in the stations. The observations from Cromer, Portsmouth, and Torquay have been discontinued; whilst those from St. Michael's Priory, near Hereford (Second Order Station), and from Aberystwith (Climatological), have been added to the list printed in the *Record*.

*The Meetings* of the Society have been well attended, and have been held as usual in the rooms of the Institution of Civil Engineers, by permission of the President and Council of that body, who have thus greatly contributed to the usefulness of this Society, inasmuch as, independently of the pecuniary saving, such commodious and central rooms could not otherwise have been obtained.

The *Catalogue* of the Library having been published in 1876, and a very large number of books having since been added to the Library, the Council took into their consideration the preparation of a new Catalogue. They decided that, instead of a supplement to the previous one, a complete Catalogue should be compiled, and that this should be arranged alphabetically, under authors' names. The Catalogue Committee consider that they have been fortunate in obtaining the services of Mr. J. S. Harding, F.R.Met.Soc., as Editor; and they believe that the volume will be distributed to the Fellows in 1890, and will be alike creditable to the Society and useful to all Meteorologists. The cost, which will probably be between £100 and £150, is already provided for.

The surplus stock of the *Society's Publications* having largely increased beyond the convenience of storage, it was decided to distribute the surplus copies of the publications dated before 1880 amongst the Fellows, after reserving 25 copies of each for stock. A notice was accordingly issued to the Fellows, and a large number of the surplus copies have been accordingly sent out.

Owing to the increase of the Library, the *shelf accomodation* has become insufficient, and no additional space being available in the Society's rooms, application was made to Mr. Barnes, from whom those now occupied are rented, and he has kindly placed several shelves at their disposal, where a large number of non-meteorological serials can be placed and obtained when required for reference. This offer has been accepted with thanks. The rooms occupied by the Society have been whitewashed, painted and repaired, and other improvements made in the accommodation, but this is insufficient for our wants. A Committee has been therefore appointed to make inquiries in the neighbourhood, but the rent asked for suitable rooms was too high. In these circumstances the Council have initiated a New Premises Fund, by investing the sum of £50 as a commencement towards the amount necessary to provide better accommodation. The Council hope that many of the Fellows will assist in carrying out this scheme.

It is to be remembered that owing to the comparative youthfulness of our Society we are in a worse position than many of the other Societies, *e.g.* all the following have rooms free of all charge, and of rates and taxes provided by Government, viz.—

| | |
|---|---|
| The Royal | The Geological |
| The Society of Antiquaries | The Linnæan |
| The Royal Astronomical | The Chemical |

and though the Royal Geographical Society is not provided with rooms, it receives a Parliamentary grant of £500 per annum "to enable the Society to provide suitable rooms in which to hold their meetings, and to exhibit to the public, free of charge, their collection of maps."

*Fellows.*—The changes in the number of Fellows during the year are shown in the following Table:—

| Fellows. | Annual. | Life. | Honorary. | Total. |
|---|---|---|---|---|
| 1888, December 31 ... | 375 | 132 | 18 | 525 |
| Since elected ............ | +68 | +4 | ... | +67 |
| Since compounded ...... | − 1 | +1 | ... | 0 |
| Deceased .............. | − 9 | −6 | −1 | −16 |
| Retired ...... .......... | −19 | ... | ... | −19 |
| Defaulters .............. | − 8 | ... | ... | − 8 |
| 1889, December 31 ... | 401 | 131 | 17 | 549 |

*Deaths.*—The Council have to announce with much regret the deaths of Sixteen Fellows, including one Honorary Member, Prof. Elias Loomis. The names are:—

| | | |
|---|---|---|
| Rt. Hon. Edward Pleydell Bouverie, M.A., F.R.S. | elected | June 15, 1864. |
| George Daniel Brumham | ,, | Feb. 17, 1869. |
| William Brown Clegram, M.Inst.C.E. | ,, | Mar. 15, 1876. |
| Warren de la Rue, M.A., D.C.L., Ph.D., F.R.S. | ,, | Apr. 17, 1867. |
| John George Gamble, M.A., M.Inst.C.E. | ,, | Feb. 18, 1880. |
| Henry Hudson, M.D. | ,, | Nov. 17, 1869. |
| Major Charles Henry Maurice Kensington, R.E. | ,, | Mar. 16, 1887. |
| Hugo Leupold, Assoc.M.Inst.C.E., | ,, | Mar. 19, 1884. |
| Major Edward Windus Mathew, D.L., J.P. | ,, | June 15, 1881. |
| James Muir, M.Inst.C.E. | ,, | May 15, 1878. |
| William Parkes, M.Inst.C.E. | ,, | June 15, 1864. |
| Rev. Stephen Joseph Perry, S.J., M.A., F.R.S. | ,, | Apr. 21, 1869. |
| James Simpson, M.Inst.C.E. | ,, | Apr. 20, 1870. |
| George William Stevenson, M.Inst.C.E., F.G.S. | ,, | Feb. 15, 1882. |
| Alfred Hope Wood, Assoc.M.Inst.C.E., | ,, | June 15, 1881. |

*APPEN-*

STATEMENT OF RECEIPTS AND PAYMENTS

### Receipts.

| | £ s. d. | £ s. d. |
|---|---|---|
| Balance from 1888 | | 342 4 2 |
| Subscriptions for 1889 | 607 16 0 | |
| Do. former years | 45 2 0 | |
| Do. paid in advance | 59 1 0 | |
| Life Compositions | 105 0 0 | |
| Entrance Fees | 48 0 0 | |
| | | 864 19 0 |
| Meteorological Office—Copies of Returns | 99 2 11 | |
| Do. Grant towards Inspection Expenses | 25 0 0 | |
| | | 124 2 11 |
| Dividends on Stock | | 61 12 2 |
| Sale of Publications | | 39 1 0 |
| Repaid by Authors for Corrections | | 2 7 0 |
| Grant for Thunderstorm Inquiry | | 30 8 6 |
| | | £1464 14 9 |

*DIX I.*

FOR THE YEAR ENDING DECEMBER 31st, 1889.

PAYMENTS.

| | £ s. d. | £ s. d. |
|---|---|---|
| *Journal, &c.:—* | | |
| Printing Nos. 69 to 72 | 140 1 0 | |
| Illustrations | 21 17 1 | |
| Authors' Copies | 14 10 0 | |
| Meteorological Record, Nos. 31 to 34 | 48 9 6 | |
| Registrar-General's Reports | 8 8 0 | |
| | | 233 5 7 |
| *Printing, &c.:—* | | |
| General Printing | 32 2 0 | |
| Forms, &c. | 8 10 6 | |
| Stationery | 19 8 8 | |
| Books and Bookbinding | 27 6 10 | |
| Revision of Library Catalogue MS. | 10 0 0 | |
| | | 97 8 0 |
| *Office Expenses, &c.:—* | | |
| Salaries | 327 8 0 | |
| Rent and Housekeeper | 48 9 0 | |
| Repairs, Coals, &c. | 13 10 0 | |
| Postage, &c. | 58 3 0 | |
| Petty Expenses | 12 17 7 | |
| Refreshments at Meetings | 13 13 7 | |
| Exhibition of Instruments | 5 13 5 | |
| | | 479 14 7 |
| *Observations:—* | | |
| Inspection of Stations | 40 18 11 | |
| Observers at Old Street and Seathwaite | 7 2 0 | |
| Instruments | 1 3 4 | |
| Wind Force Experiments | 2 13 6 | |
| Thunderstorm Discussion | 22 0 0 | |
| | | 73 17 9 |
| *Stock:—* | | |
| Purchase of £100 N. S. W. 4 per cent. Inscribed Stock .. | 114 3 0 | |
| Do. £51 5s. 8d. Consols (New Premises Fund) .. | 50 0 0 | |
| | | 164 3 0 |
| | | 1048 8 11 |
| *Balance:—* | | |
| At Bank of England | 399 10 10 | |
| In hands of Assistant-Secretary | 16 15 0 | |
| | | 416 5 10 |
| | | £1464 14 9 |

Examined and compared with the Vouchers, and found correct,

J. S. HARDING,
H. SOWERBY WALLIS, } *Auditors.*

*January* 9th, 1890.

*APPENDIX I.—Continued.*

## ASSETS AND LIABILITIES ON JANUARY 1st, 1890.

**Liabilities.**

| | £ | s. | d. |
|---|---|---|---|
| To Subscriptions paid in advance | 59 | 1 | 0 |
| ,, Grant for Thunderstorm Inquiry unexpended | 8 | 8 | 6 |
| | 67 | 9 | 6 |
| ,, Excess[1] of Assets over Liabilities | 2648 | 1 | 4 |
| | £2715 | 10 | 10 |

[1] This excess is exclusive of the value of the Library and Stock of Publications.

**Assets.**

| | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| By Investment in M. S. & L. R. 4½ Debenture Stock, £800 at 141 | 1128 | 0 | 0 | | | |
| ,, Investment in N. S. W. Stock, 4 per Cent. Inscribed, £600 at 114 | 684 | 0 | 0 | | | |
| ,, Investment in 2¾ per Cent. Consols, £250 at 97¼ | 243 | 2 | 6 | | | |
| ,, Do. £51 5s. 8d. (New Premises Fund) | 49 | 17 | 6 | | | |
| | | | | 2105 | 0 | 0 |
| ,, Subscriptions unpaid, estimated at | 40 | 0 | 0 | | | |
| ,, Entrance Fees unpaid | 23 | 0 | 0 | | | |
| ,, Interest on Stock | 31 | 5 | 0 | | | |
| | | | | 94 | 5 | 0 |
| ,, Furniture, Fittings, &c. | 30 | 0 | 0 | | | |
| ,, Instruments | 70 | 0 | 0 | | | |
| | | | | 100 | 0 | 0 |
| ,, Cash in hands of Bank of England | 399 | 10 | 10 | | | |
| Do. the Assistant-Secretary | 16 | 15 | 0 | | | |
| | | | | 416 | 5 | 10 |
| | | | | £2715 | 10 | 10 |

J. S. HARDING, } *Auditors.*
H. SOWERBY WALLIS, }
WILLIAM MARRIOTT, *Assistant-Secretary.*

*January 9th*, 1890.

## *APPENDIX II.*

## REPORT ON THE INSPECTION OF THE STATIONS, 1889.

All the stations in Wales and the South-west of England have been visited this season, and were found to be in a satisfactory condition.

The alterations in the zeros of the thermometers were more numerous than I have found in any previous inspection. This is, no doubt, largely due to the fact that three years have elapsed since the last inspection. The following is a summary of the changes in the zeros of the thermometers :—

| Dry. | Wet. | Max. | Min. | Earth. |
|---|---|---|---|---|
| 5 risen 0°·1 | 6 risen 0°·1 | 2 risen 0°·1 | 1 risen 0°·2 | 1 risen 0°·2 |
| 7 „ 0·2 | 5 „ 0·2 | 2 „ 0·2 | 1 „ 0·1 | 1 „ 0·3 |
| 8 „ 0·3 | 2 „ 0·3 | 1 „ 0·3 | 1 gone down 0·1 | 2 „ 0·4 |
| | | | 4 „ 0·2 | |
| | | | 1 „ 0·3 | |
| | | | 1 „ 0·4 | |
| | | | 1 „ 0·7 | |
| | | | 1 „ 2·2[1] | |

At two stations Negretti and Zambra's pattern of earth-thermometer is in use. In this instrument the thermometer is enclosed in a thick glass tube, with the bulb and a portion of the stem also embedded in wax. The thermometer is consequently exceedingly sluggish; so much so that I was quite unable to compare it with my standard thermometers.

In three instances the thread of mercury forming the index in Phillips's maximum thermometer had become so long that there was a risk of the air bubble working into the bulb and throwing the instrument out of order. These indices I shortened considerably by placing the bulb in a mixture of salt and ice, which reduced the temperature nearly to zero.

When in Wales I called upon Dr. Rees Davies, the Medical Officer of Health at Aberystwith, and asked him if he would observe for the Society. This he has agreed to do. The instruments belong to the Corporation of Aberystwith, and are mounted in the enclosure selected by Mr. Symons in 1875. A Jordan sunshine recorder has recently been obtained. We may now expect some valuable observations from that part of Wales.

WILLIAM MARRIOTT.

*October 15th, 1889.*

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## NOTES ON THE STATIONS.

ABERYSTWITH, *July 22nd.*—I called upon Dr. D. Rees Davies, the Medical Officer of Health, and found that he was willing to furnish the Society with observations. The instruments are in the same position as

[1] This was a grass minimum. The change was not due to the condensation of spirit at the top of the tube.

described in Vol. III. p. 58. On comparing the thermometers I found that the zeros of the dry and wet had risen 0°·8, the maximum 0°·1, and the minimum decreased 0°·4. A Jordan sunshine recorder has recently been added to the station.

ASHBURTON, *September 4th.*—The rain-gauge had been moved about 12 feet south of its former position about two months previous to my visit. The thermometer screen required to be painted and made firmer. The zeros of the maximum and dry bulb thermometers had risen 0°·2, and the minimum had decreased 0°·2.

BABBACOMBE, *August 28th.*—The station was in good order. Some slight changes had taken place in the zeros of most of the thermometers since the last inspection in 1886. The grass minimum thermometer had however been broken, and the zero of another one, which was being used in its place, was found to have decreased 2°·2 in the past year.

BRAMPFORD SPEKE, *August 26th.*—The instruments were in the same position as at the last inspection. The thermometer screen required painting. The zeros of the dry and wet bulb thermometers had risen 0°·3.

BUDE, *September 3rd.*—There was no change in the thermometers. Mr. Arthur contemplates discontinuing the observations at the end of 1890.

BURGHILL, *July 18th.*—As trees had grown up very much in the neighbourhood of the thermometer screen, I recommended that it be moved to a more open situation. The screen also required painting. As the shrubs round the rain-gauges had also grown very much Dr. Chapman was requested to move one of the gauges further to the north.

BUXTON, *July 25th.*—The observations have been in charge of Mr. W. H. Beck since February. The thermometers were all correct. The column of mercury in the maximum however was very long, and was liable to get out of order. The Jordan sunshine recorder was not firmly fixed, and required adjustment.

CARMARTHEN, *August 23rd.*—Dr. Hearder was away at the time of my visit, but the deputy observer showed me the instruments. The thermometers were all correct except the wet bulb, which had gone up 0°·2.

CHELTENHAM, *July 17th.*—The thermometers required re-arranging in the screen. The zeros of the mercurial thermometers had risen: the dry 0°·2, wet 0°·1, maximum 0°·3.

CHURCHSTOKE, *July 20th.*—The thermometer screen, which was fixed on one stout post, was rather shaky. I recommended that it be fixed on four posts. The thermometers were all correct. The sunshine recorder is placed on the tower of Mellington Hall, and has a very open exposure.

CULLOMPTON, *August 26th.*—This station was in good order. The thermometers were correct except the wet bulb, which had gone up 0°·2. The earth thermometer is now not used. The sunshine recorder is mounted on an iron plate fixed on the top of a lamp post, which is built into a brick pier. The exposure is very good; the glass shade which formerly covered the recorder has been removed.

EXETER, *August 27th.*—I called at the Hospital and found that no

observations had been made since the Rev. P. H. Newnham's death. Dr. R. Coombe, the House Surgeon, agreed to take the observations for a month as an experiment, and then if satisfactory, to continue them. The thermometer screen required painting.

FALMOUTH, *August 31st.*—The station was in good order. The zeros of the dry and wet bulb thermometers had gone up 0°·1.

GWERNYFED PARK, *July 19th.*—This station is close to Three Cocks Junction, Brecknockshire, 5 miles South-west of Hay, and 8 miles North-west of the Black mountains. The situation and exposure are very open. Since my visit the station has been equipped so as to fulfil the requirements of the Society.

ILFRACOMBE, *August 24th.*—The funnel of the rain-gauge had become corroded and required attention. A new funnel with deeper rim was subsequently ordered, and put in position on January 1st, 1890. The zero of the dry-bulb thermometer had risen 0°·2.

LLANDUDNO, *July 24th.*—The exposure of the instruments was much better than at the previous inspection; the shrubs, &c. having been cleared away, and a plot of grass laid down. The minimum thermometer had 0°·3 of spirit at the top of the tube. The sunshine recorder is mounted on the roof of the Old Telegraph Station on the top of the Great Orme's Head, where the exposure is very good. The recorder, however, was not in good adjustment.

MARLBOROUGH, *July 16th.*—The muslin on the wet-bulb thermometer required changing. The zero of the dry-bulb thermometer had gone up 0°·3. The grass minimum thermometer had some spirit at the top of the tube. The earth thermometers, which are enclosed in a thick outer tube, and have the bulb surrounded by wax, are so sluggish that it was impossible to test them. As Mr. Storey had left the College, the instruments were again under the charge of Mr. Hewitt.

OAKAMOOR, *July 24th.*—The maximum was inclined with the bulb slightly upwards, so that the thermometer had to be gently tilted before it could be read. I altered the position of the maximum and minimum, so that, no doubt, better results will now be obtained. The thermometer screen required painting.

PRINCETOWN, *August 30th.*—The zeros of the dry and wet bulb thermometers had risen 0°·1. The thermometer screen required painting. The observations in the morning are taken by Mr. Hamick, a warder, and in the evening by Dr. Stone, who always reads the barometer. It appears that the officials of the prison open the door of the thermometer screen occasionally during the day, and look at the thermometers.

ROSS, *July 17th.*—The thermometer screen and rain-gauge were better exposed than at the previous inspection, as a number of shrubs had been cut down. The screen had also been mounted on four posts. The muslin on the wet bulb required changing.

ROUSDON, *September 5th.*—On comparing the thermometers it was found that the 1 ft. and 4 ft. earth thermometers had risen 0°·4, and the 2 ft. 0°·3,

while the minimum thermometer had gone down 0°·2. As the present site, which is in a kitchen garden, is somewhat sheltered, Mr. Peek proposes removing the instruments to a more open situation near the Astronomical Observatory on January 1st, 1890. Simultaneous readings will be taken at both sites during the next three months. In addition to the ordinary instruments Mr. Peek has also a large cup anemograph (on the Water Tower), a Gordon electrical anemometer, a Richard barograph, and 8 evaporation tanks.

SIDMOUTH, *August 27th.*—The station was in good order. The zero of the dry bulb thermometer had gone up 0°·2, and the wet 0°·1.

ST. MICHAEL'S PRIORY, *July 18th.*—I called here and selected sites for the instruments which Canon Howlett proposes putting up. The exposure is very good. St. Michael's Priory is 2½ miles South-west of Hereford. It is anticipated that the observations will be continuous during the vacations, as there are always some Professors in residence.

STOWELL, *August 21st.*—This station was in good order. The zeros of the dry and wet bulb thermometers had gone up 0°·2, and the minimum had gone down 0°·3. The earth thermometer was so sluggish that it could not be tested. In addition to the usual instruments the Rev. H. J. Poole has a Jordan sunshine recorder, a Richard barograph and thermograph, and a percolation gauge.

TEIGNMOUTH, *August 29th.*—The instruments are in the same position as at the last inspection. The screen had recently been fixed on new posts and painted. The minimum thermometer had gone up 0°·2.

TORQUAY, *August 28th.*—Mr. Chandler has a set of instruments in the grounds of the Devon Rosary, which are well exposed except on the east. The Jordan sunshine recorder is mounted on a stone pier on the top of Chapel Hill, near Torre Railway Station. The exposure is very good.

WESTON-SUPER-MARE, *August 22nd.*—The instruments were in the same position as at the previous inspection. The dry and wet bulb thermometers had gone up 0°·2. The screen required painting.

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## *APPENDIX III.*

## OBITUARY NOTICES.

THE RIGHT HON. EDWARD PLEYDELL BOUVERIE was born in 1818, and was the second son of the third Earl of Radnor. He was educated at Harrow and at Trinity College, Cambridge, where he graduated M.A. in 1838. He entered public life very soon after leaving the University. From January to June 1840 he was précis writer to Lord Palmerston.

He was called to the Bar at the Inner Temple in 1843, and in the following year he was returned to Parliament in the Liberal interest as Member for Kilmarnock, which constituency he continued to represent until 1874, when

he was an unsuccessful candidate. During his 30 years of Parliamentary life Mr. Bouverie was a prominent figure in the House of Commons. From July 1850 to March 1852 he was Under-Secretary of State for the Home Department, and from April 1853 to March 1855 he was Chairman of Committees. In March 1855 he was made Vice-President of the Board of Trade, and in August of the same year he vacated this office and became President of the Poor Law Board, which position he held until 1858. In 1857 he was appointed one of the Committee of Council of Education. He was Second Church Estates Commissioner from August 1859 until November 1865, and from the year 1869 he was one of the Ecclesiastical Commissioners for England.

Mr. Bouverie was also a director of many great companies, among them being the Great Western Railway Company, and the Peninsular and Oriental Company.

Mr. Bouverie was at one time a prolific contributor to the correspondence columns of *The Times*, and his letters, which appeared over the signature "E. P. B.", more especially those on the subject of the Bulgarian atrocities in the autumn of 1876 and the following year, were widely read and widely commented on.

He died on December 16th, 1889.

Mr. Bouverie was elected a Fellow on June 15th, 1864.

George Daniel Brumham was born December 20th, 1827, at Sandy, in Bedfordshire, but removed to London at an early age. Entered first as a clerk, he subsequently became a member of the Stock Exchange, with which he was connected for a quarter of a century. He continued a member for some few years after retiring from active practice, but eventually devoted himself almost wholly to Meteorology. He was elected Fellow on February 17th, 1869, and contributed to the Society the following papers:—

"On some of the Laws which appear to regulate the Temperature of Months and Seasons." *Proceedings*, Vol. IV. p. 75.

"On some of the Laws which appear to regulate the Temperature of Summer months and Seasons." *Proceedings*, Vol. V. p. 129.

"On the Moon's influence in connection with extremes of Temperature." *Quarterly Journal*, Vol. III. p. 30.

He also wrote many articles and letters in the *Meteorological Magazine* upon the subject to which he devoted almost lifelong care and work, viz. the elaboration from the records of the past of rules indicative of the probable character of future seasons.

Mr. Brumham's health was never strong, and he was carried off by an attack of bronchitis on April 20th, 1889.

William Brown Clegram, whose death occurred on the 3rd of June 1889, was born on the 1st of October 1809 at Shoreham, Sussex, where his father, who began life as a sailor, had settled in order to take charge of improvement works designed by him for the harbour at that place. He was

brought up by his father to the profession of a civil engineer, and before he quitted Shoreham in 1827 had assisted him in his drawings and surveys. At this time Mr. Clegram, senior, was selected to take charge, under Mr. Telford, of the Gloucester and Berkeley ship-canal, then not yet completed. His son almost at once entered the same service, being appointed Clerk in 1829.

Whilst holding this office he had leisure to assist his father in designing new basins, quays, graving-docks and other works at Gloucester; and in 1861 he succeeded to the post of Engineer and Superintendent. At this time the important and practically untried system of towing by means of screw steam-tugs was introduced on this canal, and formed the subject of a Paper he presented to the Institution of Civil Engineers entitled "Results of the Employment of Steam-Power in Towing Vessels on the Gloucester and Berkeley Canal."[1]

Mr. Clegram was always an ardent advocate for the retention and improvement of the water-ways of the country, and had more than once to sink personal feelings in their defence as well as to embark capital in their advancement.

In conjunction with the late Mr. T. E. Harrison, C.E., he carried out important improvements at the sea entrance to the canal at Sharpness, the position of which was the subject of long and mature deliberation, rendered none the easier by the consideration that it was necessary to provide access for vessels of some 3,000 tons displacement in a channel where the tide frequently set at the rate of 7 knots an hour. That these works proved equal to the requirements of the trade of the district for fifteen years is evidence of his sound judgment and power of acquiring technical knowledge from others; and that they can scarcely be said now to be on this footing is due to the fact that Mr. Clegram had to make the most of funds, provided in a great measure by his untiring activity, in a district not specially favoured with a redundant or too wealthy population. The works consisted of open wooden piers on either side of the entrance into a tidal basin, with lock, floating-basin, graving-dock, and connecting-cut to the old works. He was also one of the prime movers in the founding of the Severn Bridge.

Perhaps the chief noticeable features of his character were the wide range of his attainments, and the thoroughness with which he was wont to grasp every detail of the work he set himself to carry through. He was a good artist, a keen observer of nature, with both microscope and telescope, a great reader, and an accomplished musician. To all about him he was ever considerate and courteous, with a kind word for every one with whom he came in contact. His advice was at all times eagerly sought by his more intimate friends, and his judgment relied upon as sound and trustworthy. He was, like his father, a systematic recorder of daily events, small and great, which included meteorological observations.

He was elected a Fellow of this Society on March 15th, 1876.

[1] *Minutes of Proceedings Inst. C.E.*, Vol. XXVI. p. 1.

WARREN DE LA RUE was born at Guernsey on January 18th, 1815, and was the son of Mr. Thomas de la Rue, the founder of the eminent firm of manufacturing stationers in London. He was educated at the College Saint-Barbe in Paris, where he remained until he returned to London to enter his father's business. He subsequently succeeded his father as head of the firm, from which he retired in 1880.

In the course of his conduct of the firm Mr. de la Rue applied his scientific knowledge to purposes of practical utility and patented a number of inventions, among them being processes for utilising earth oils, and machinery for simplifying the making of writing materials.

The principal scientific work in which he distinguished himself was the application of photography to the recording of celestial phenomena. The photographs, when measured by a micrometer which he invented, furnished exact astronomical data. In 1860 he went to Spain with the "Himalaya" Expedition, and was successful in obtaining a series of photographs of the total eclipse of the sun on July 18th. In conjunction with Professor Balfour Stewart and Mr. B. Loewy, he published "*Researches in Solar Physics*," founded on observations made at the Kew Observatory under his directions. He also took an active part in making the preparations for the photographic observation of the transit of Venus in 1874.

Mr. de la Rue established a private observatory at Cranford, Middlesex, but it was dismantled in 1873, and the instruments presented to the University of Oxford. He acted as juror and reporter in the Department of Class XXIX. in the Great Exhibition of 1851, was a juror in Class X. of the Paris Exhibition of 1855, and presided over Section B, Class XXVIII. of the Exhibition of 1862. He has held office in several societies. He acted for some time as Secretary of the Royal Astronomical Society, of which he was also President from 1864 to 1866. He was President of the Chemical Society from 1867 to 1869 and again in 1879-80, and was till his death one of its Vice-Presidents. He was for many years President of the London Institution, from which he retired and became Secretary of the Royal Institution in 1878, but resigned the post in 1882. He was a corresponding member of many foreign scientific societies.

Mr. de la Rue was for several years a Member of the Kew Committee and also of the Meteorological Council. He was elected Chairman of the Kew Committee on the death of Sir E. Sabine in 1883.

He was elected a Fellow of this Society on April 17th, 1867.

He died on April 19th, 1889, aged 74.

J. G. GAMBLE.—The Society has lost a sincerely appreciative as well as a hard working Fellow by the death, of typhoid fever, at the age of 47, of Mr. John George Gamble, M.A., M.Inst.C.E., which took place on November 7th, 1889, at Dublin, where he held the appointment of Chief Hydraulic Engineer to the Government, and where in regard to the important schemes on which he was engaged his loss will be much felt.

Mr. Gamble was a man of considerable scientific and other attainments, having distinguished himself at Oxford by taking high honours both in the Classical and Mathematical Schools, and it may be mentioned that he there obtained the Gold Medal for the Johnson Memorial Prize Essay in 1871, the subject of the Essay being "The Laws of Wind."

He subsequently became a pupil to Sir John Hawkshaw, the eminent Civil Engineer, and while with him he was engaged in connection with the carrying out of important docks and other works, and he communicated papers which were read before the Institution of Civil Engineers in 1875, and the British Association in 1872, on the Brighton Intercepting and Outfall Sewers, of which work Mr. Gamble was the Resident Engineer under Sir J. Hawkshaw. He also acted as one of the local secretaries to the Mechanical Science section of the British Association at the Brighton Meeting in 1872.

After being engaged on an important investigation under Sir J. Hawkshaw on the Harbours of Brazil, he became in 1875 Chief Hydraulic Engineer to the Government of the Cape of Good Hope, where he designed and executed important works for domestic water supply, irrigation, and storage of water; and his reports in this capacity, extending over the period 1876-85, contain many valuable papers on these subjects.

Soon after his arrival in the Colony Mr. Gamble recognised the important bearing of Meteorological phenomena on the work of the Hydraulic Engineer, particularly as exemplified in the results of observations of temperature and rainfall, on which subjects he wrote several papers of considerable interest and value.

He found at the commencement that there was a great deficiency of records of rainfall; those, however, which existed were analysed, and in 1878 we find that a paper was contributed by him to the South African Philosophical Society, giving a list of 28 Rainfall stations, and in connection with which four seasonal maps were exhibited.

A complete list of the papers written by him on Meteorological and other subjects would occupy too much space, but we may mention that on the "Rainfall of South Africa," contained in the *Quart. Jour. R. Met. Soc.* Vol. VII. p. 8, which gives some account of the state of Meteorological knowledge in South Africa previously existing, and of the steps taken by Government to improve it; and as conducing to this end much might be said as to the effect of Mr. Gamble's influence in arousing interest in the subject, and in infusing vitality into the operations.

He became in 1877, and continued until his death, a Member of the Meteorological Commission which had existed for some years previously to his arrival in the Colony, and at some of the works carried out by him in exceptional localities observations established by him of evaporation and other matters have given interesting results.

Some of the more important of Mr. Gamble's labours in connection with this subject, are the Tables of average Rainfall from 75 stations, being all those in the Colony at which records had been kept for at least 5 years, contained in the *Met. Com. Rep.* for 1888, diagrams plotted from which were published in the Report of the succeeding year.

At the Colonial Exhibition held in South Kensington in 1886 Monthly and Yearly Maps of the Mean Rainfall of the Cape Colony by Mr. Gamble were exhibited, and these were subsequently reproduced in the *Met. Com. Rep.* for that year, which also includes the Rainfall Returns, which had in these few years increased to 275 stations.

Another was a Catalogue of printed books and papers relating to the Climate and Meteorology of South Africa, contributed to the *South African Phil. Soc.* Vol. II. Part II.

Mr. Gamble was elected President of the above-named Society for the year 1881-2, on which occasion his address was on "The Barometer and the Winds."

Another interesting paper on "Water Supply in the Cape Colony" was printed in Vol. XC. of the *Min. Proc. Inst. C.E.*

In addition to his other subjects of interest, Mr. Gamble paid much attention to the subject of higher Education in the Colony.

He was an examiner and a Member of Council of the Cape University, in the work connected with which he took a large share, and the high degree of culture possessed by him, as well as the assiduity with which he applied himself to matters in which he took part, rendered his departure from the Colony a loss deeply deplored in many quarters.

Mr. Gamble was exceedingly conscientious, and he carried out with great energy and ability all he undertook; he was also exceedingly unassuming in his manners, although his knowledge extended over a wide range of subjects, and his memory will long be highly esteemed by a large circle of friends.

He was elected a Fellow of this Society on February 18th, 1880.

Prof. Elias Loomis was born on August 7th, 1811, at Willington, Connecticut. He was appointed Tutor at Yale College in 1833, but he spent a year, 1836-7, in Paris. On his return he held professorships in various colleges till 1860, when he was appointed Professor of Astronomy at Yale, an office which he held till his death on August 15th, 1889.

Prof. Loomis began publishing papers on storms in 1838, and his *Smithsonian Contribution* "On certain Storms in Europe and America, December 1836," was dated 1839. He wrote a number of school text-books of science. His *Treatises* on Meteorology and Astronomy are both well known in this country. His books are said to have attained a sale of 500,000 copies.

His most important work has been the preparation of his "Contributions to Meteorology," originally issued in *Silliman's Journal.* He was engaged up to the time of his death in a republication of these in quarto form.

He was elected an Honorary Member of this Society on June 17th, 1874.

Edward Windus Mathew was the son of Mr. Nathaniel Mathew, of Wern, Carnarvonshire, and was born in 1812. He was a J.P. and D.L. for county Carnarvon, and was for some time Major-commanding the 4th Carnarvonshire Rifle Volunteers. His family were connected with large slate quarries in Wales, and carried out extensive quarry works in conjunction with Lord Penrhyn.

He removed to Guildford about ten years ago, where he took a lively interest in meetings of a social and political nature.

He was a devoted student of Meteorology, and contributed largely to the scientific journals.

He died on October 26th, 1889, in the seventy-seventh year of his age.

He was elected a Fellow of this Society on June 15th, 1881.

James Muir was born at Glasgow on May 31st, 1817, his father being the Rev. William Muir, D.D., LL.D., a minister of the Established Church of Scotland, afterwards of St. Stephen's, Edinburgh, and one of Her Majesty's chaplains in Scotland. Mr. Muir was educated at Edinburgh, where he attended first the High School, and then the Academy, completing his education at the University. Whilst awaiting an opening that would form an introduction to civil engineering, he assisted Mr. John Scott Russell, under whom he had formerly studied, in investigating the laws that govern wave motion and that affect the movement of floating bodies through water. At the age of eighteen he came to London, and was articled to the Messrs. J. and G. Rennie of Blackfriars. There Mr. Muir was employed in the office and workshops until the year 1841, when he entered the service of the New River Company, London, as assistant to Mr. W. C. Mylne, F.R.S. Whilst so engaged he designed a water-meter which was found to be a great improvement upon the then existing apparatus, and he was thereupon highly commended by the Directors of the Company for his ingenuity.

On the resignation of Mr. Mylne in 1859, Mr. Muir was appointed Engineer to the Company. From this time until his retirement he was energetically occupied in extending the sources of the supply, in improving the means available for its distribution, and in maintaining its quality at the highest standard of purity attainable. In order to meet the heavy demands that arose from extension of building, and the increased use of water for sanitary purposes, he sank numerous deep wells into the chalk between Hertford and London. By deep boring at two of the wells, viz. those at Ware and at Turnford, he solved the question, so far as the country northward of London is concerned, of the possibility of finding a new source of water for the supply of the Metropolis in the Lower Greensand, a question that was formerly much discussed by geologists. At both of the places named the stratum sought was found to exist, but in a very attenuated form and quite devoid of water.

A matter that frequently engaged his attention was the enlargement of the channel of the New River along which the supply is conveyed to town. This artificial watercourse having been formed more than 270 years since, has from time to time needed much alteration to fit it for present requirements. In pursuit of this object, Mr. Muir renewed the aqueduct at places where diversion of the stream was required; added auxiliary conduits where the sectional area was restricted, and by various ingenious methods largely increased the carrying capacity of the channel. The rapid growth of the northern suburbs of London early necessitated the construction of an enlarged

filtering and pumping station at Hornsey, where under his direction provision was made for lifting large quantities of water to reservoirs on the tops of the ridges extending from Hornsey to Hampstead. Among the number of these newly-made Reservoirs a pair at Crouch Hill, having a total capacity of 12,000,000 gallons, were constructed in the face of considerable engineering difficulties arising from the treacherous nature of the sub-soil.

Shortly after his appointment as Engineer to the Company Mr. Muir re-arranged the whole system of distributing mains throughout the town districts, forming zones of supply at the various levels corresponding to several reservoirs. This involved the laying of a great number of pipes varying in size up to 36 inches in diameter, and the arrangement of many new connections, the work being often carried on under great disadvantages owing to the crowded state of underground London, and the many interests, municipal and other, that must necessarily be consulted.

In 1872, when the regulations for prevention of waste of water were framed by the Board of Trade, as prescribed by the Metropolis Water Act of the preceding year, he took an active part in collecting materials that would be of service in their compilation, his aim being to obtain for London the advantages that are possessed by most of the larger municipal Corporations, in the way of ability to prevent waste of water without restricting its use for domestic purposes. With this end in view he also took great interest in all newly-invented water fittings, whether for domestic or public use. Among the many details appertaining to the various structures and appliances used in waterworks, which had his studious and indefatigable attention, may be mentioned the arrangement of the filtering medium in filter beds. He first introduced the method, which has now become general, of forming small drain channels of common bricks laid dry in rows at the bottom of the bed, with a closely-paved covering of the same above, upon which shingle for supporting the sand rests.

In the course of many inquiries concerning such matters as Water Supply, Pollution of Rivers, &c. that have from time to time been conducted by Royal Commissions and Parliamentary Committees, Mr. Muir was often called upon to appear as a witness, in which capacity he greatly excelled, impressing all who heard him by the readiness of his replies, and by the full and lucid, but at the same time concise, manner in which he answered questions, whether from friendly or opposing counsel. Another direction in which he showed talent to a remarkable degree was in dealing with financial affairs, for which he evinced a special aptitude. Thus it frequently happened that he was able to effect considerable economies, without in any way lessening the value of the final results.

In the year 1882, having fallen into ill-health, Mr. Muir was relieved from active duty, and accepted the post of Consulting Engineer to the Company. In the succeeding year he was elected a Director, and, notwithstanding that he then resided at Bournemouth, was unremitting in his attendance at the weekly Board Meetings until about midsummer of the year 1888, when he was seized with the illness which, after a long and painful course, terminated in his death on January 4th, 1889.

Mr. Muir was most conscientious and scrupulous in all his dealings, and earnestly strove to imbue his subordinates with his own intense devotion to duty. He combined a kindly and gentle disposition with great firmness and love of discipline. His judgment was much esteemed by those who were professionally associated with him, whilst his courteous manner and readiness to assist with judicious counsel made him respected and trusted by all who knew him. In private life he was always deeply interested in works of benevolence, to some of which he unobtrusively devoted himself, especially bestowing much time to the instruction and improvement of the young.

He was elected a Fellow of this Society on May 15th, 1878.

William Parkes was born near Gloucester on October 6th, 1822. He was educated at Bristol College and at University College, London, and being at that time of a delicate constitution, the doctors advised him to adopt a profession which would give him as much outdoor life as possible. With this view he entered the office of Mr. Hemming, an engineer in Bristol, in 1838, and after being there for a certain time, he obtained employment under the contractor who was then constructing the Great Western Railway.

In 1845 he entered the office of the late Mr. James Walker, Past-President, Inst. C. E., and while with him assisted in the preparation of the surveys and plans for various large works.

In 1847 he was sent to Alderney by Mr. Walker to report on the proposed harbour there, and, on the commencement of the works shortly afterwards, he acted as Resident Engineer under Mr. Walker, holding the position for two years.

In 1849 Mr. Parkes returned to London, and early in 1850 he started an office of his own in Parliament Street. He still retained his connection with Mr. Walker, who employed him to make reports and surveys for the River Dee Improvement scheme and other works of a similar nature in England, besides which he made surveys for various railways which were then in contemplation.

In 1853 he was asked by Mr. (now Sir) C. H. Gregory to go to Italy to superintend the work of draining Lake Fucino, but after spending a considerable amount of time and trouble the work was taken out of the hands of the English Engineers, and Mr. Parkes returned to England. About this time Mr. Walker having been requested to report on the proposal to construct a harbour at Kurrachee, Mr. Parkes was deputed to go to India to make surveys and gather materials for the report, and on his return he prepared the plans for the breakwater in conjunction with Mr. Walker, but no work was started at Kurrachee for some years afterwards. In 1860 Mr. Parkes was employed in the designing and erection of several lighthouses in the Red Sea and the Cerigo lighthouse in the Mediterranean. In 1864 he presented to the Institution of Civil Engineers a description of this work, for which he was awarded a Telford premium.[1] He also superintended the construction in

[1] *Minutes of Proceedings Inst. C.E.*, Vol. XXIII. p. 1.

England of the lighthouse which was erected on the Island of Sombrero in the West Indies.

In 1868 he went out to Kurrachee, and the construction of the breakwater was commenced, Mr. W. H. Price being left in charge of the work as Resident Engineer, and Mr. Parkes returning to England with the appointment of Consulting Engineer. This breakwater, which was completed in 1873, was the first instance of the now well-known "sloping-block" system being carried out on a large scale.

In 1873 Mr. Parkes was instructed to go to Madras to report as to the formation of a harbour at that place, and in 1875 he submitted to the Government his proposed design, consisting of two parallel breakwaters running out from the shore and turned round at the ends. This was accepted, and work was started there in 1876, Mr. Parkes going out to Madras to organise the staff and set the works going. The harbour was on the point of completion in 1882, when a cyclone visited Madras, which had the effect of destroying the outer arms of the breakwater, and a Committee of leading Engineers was appointed in London to consider the best way of restoring the works, and on their recommendations the ruined portions of the breakwaters were ordered to be reconstructed on a strengthened design, which work is still in progress.

At the time of his death Mr. Parkes was still acting as Consulting Engineer to the Madras Harbour Works, and was also the Engineering agent for the supply of wharf materials, dredging plant, &c. to the Kurrachee Port Trust, for the inner improvement of the harbour.

His sudden death from heart disease at his house at Surbiton on February 2nd, 1889, caused the greatest sorrow, not only to his immediate relatives, but to a large circle of friends both in London and at Surbiton, where for many years he had taken a prominent part in the management of local affairs.

He was elected a Fellow of this Society on June 15th, 1864.

Stephen Joseph Perry was born in London on August 26th, 1833, and was the son of Mr. Stephen Perry, a member of a well-known firm in Red Lion Square. He received his early education at Gifford Hall School, and then went to France to study at the College at Douay, where he was so successful in his mathematical work as to carry off the first prize. From Douay he proceeded to the English College at Rome for theological training, as he was destined for the priesthood, and in 1853 he entered the Society of Jesus.

It was in 1856 that Father Perry first came to Stonyhurst College, to go through the usual course of mental philosophy and physical science. His special aptitude for mathematics was soon perceived, and in the same year he was appointed to assist the Rev. A. Weld, who was then Director of the Observatory. In 1858, on matriculating at the London University, he went up for mathematical honours, taking the sixth place. After this he was sent to London for a year to study under Professor De Morgan, and then for

another year to Paris, where he attended the mathematical lectures of Liouville, Delaunay, Serrat, Cauchy, and Bertrand.

In the autumn of 1860 he returned to Stonyhurst, being appointed Professor of Mathematics and Director of the Observatory, as successor to Father Weld, who had held that position for many years. In the autumn of 1863 he left to complete his theological course at St. Beuno's College, in North Wales, where he was ordained priest in 1866; and when all his studies were completed he came back finally to Stonyhurst in 1868 to resume charge of the Observatory, which he continued to direct until the day of his death.

Father Perry carried out a magnetic survey of the west of France in 1868, and of Belgium in 1871; the results of which were published in the *Philosophical Transactions*. He also took part in a number of astronomical expeditions sent out from this country. In 1870 he was chosen as chief of the expedition to Cadiz to observe the total eclipse of the sun; and in 1874 was appointed to the command of the expedition to Kerguelen Island to observe the transit of Venus. In 1882 he again took charge of an expedition to the South-west coast of Madagascar to observe the transit of Venus. He also went out to observe solar eclipses in the West Indies on August 29th, 1886, and at Pagost, on the Volga, on August 19th, 1887.

Father Perry took charge of the Royal Astronomical Society's expedition to French Guiana to observe the total solar eclipse on December 22nd, 1889. The weather, however, was wet and very unhealthy, and he fell ill with dysentery. He managed to bear up and take some successful photographs, but he rapidly became worse and died on the 27th.

He was elected a Fellow of this Society on April 21st, 1869, and served on the Council in 1874-75. He was elected a Fellow of the Royal Society in 1874, and received the honorary degree of D. Sc. from the Royal University of Ireland in 1886.

James Simpson, the eldest son of the late Mr. James Simpson, Past-President of the Institution of Civil Engineers, was born on January 10th, 1829, at Thames Bank, Chelsea, the residence of his father, who was at that time Engineer to the Chelsea Waterworks Company. He was educated at St. Peter's Collegiate School, Eaton Square, and at Dr. Lord's private school at Tooting. In 1846 he was articled to Messrs. Burns and Bryce, Architects, Edinburgh, where he lived with the late Dr. John Brown.

Returning to London in 1851 he joined his father, who was at that time engaged in an extensive practice as a civil engineer, and superintended for him the execution of several important works, amongst others the construction of the waterworks at Carlisle and the extension of the Chelsea Waterworks Company to Surbiton, Surrey. In 1857 he joined the firm of Simpson and Company, manufacturing engineers, taking a leading part in the introduction of improved pumping-plants, especially the Woolf Compound Pumping-Engines, and in the construction of waterworks abroad.

For the past few years failing health prevented close attention to business,

although to the last he took a lively interest in all matters connected with engineering. He was much respected by those in his employ, as well as by others with whom he was associated, not only for his kindness of disposition, but also for his readiness to impart knowledge. His health gradually failing, he died at Brighton on May 11th, 1889, and was buried at Brompton Cemetery.

He was elected a Fellow of this Society on April 20th, 1870.

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## *APPENDIX IV.*

### BOOKS PURCHASED DURING THE YEAR 1889.

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## *APPENDIX V.*

### DONATIONS RECEIVED DURING THE YEAR 1889.

*Presented by Societies, Institutions, &c.*

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## *APPENDIX VI.*

### REPORTS OF OBSERVATORIES, &c.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of the Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav.-Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

MARINE METEOROLOGY.—*Current Charts for all Oceans.*—The extraction of data for these charts has made steady progress. All the information contained in the 7,800 logs in the office has been transferred to the charts, and the Remark Books of H.M. Ships are now under examination. Some 800 of these, covering about three years, have already been dealt with.

*The Meteorology of the Red Sea, and also of Cape Guardafui.*—The monthly charts for these two areas, closely adjacent to each other, are almost ready for the engraver. Those of the Red Sea only require the insertion of generalised current arrows. Those for Cape Guardafui are as complete as the amount of information available will allow.

*The Aden Cyclone Charts.*—These are now complete and in the engraver's hands. They consist of daily charts for the period of six weeks, covering the duration of the storm and the conditions which preceded and succeeded it respectively.

*The Cyclone Track Charts of the South Indian Ocean.*—These charts were originally submitted by Dr. Meldrum to the British Association, and subsequently handed over by him to the Meteorological Council, who directed that the information, originally in the form of yearly charts, should be rearranged in order to obtain monthly charts. This has been carried out, and the charts have gone to press. There are nine of them, the cyclones only appearing in ten months, and being so rare in June and July that the information for the two months is given on one chart. Dr. Meldrum's original yearly charts will also be reproduced.

*The Charts of Barometrical Pressure for all Oceans.*—Two supplementary charts have been issued, one showing the mean barometrical pressure throughout the year, and the others indicating the extent of range of irregular fluctuations. The information contained in this latter chart presents us with some features of considerable interest.

*The Meteorology of the South Sea.*—The next region to be discussed by the office, and on which work a good commencement has been made, is that lying between Long. 40° and 180° E, and to the Southward of Lat. 35°. This comprises the track from the Cape of Good Hope to New Zealand.

WEATHER TELEGRAPHY.—No change of great importance has been made in this department. *The Weekly Weather Report* has been further enlarged by the addition of monthly supplements, which have taken the place of the Monthly Weather Report.

*The Fishery Barometer Inspection* has been continued, and comparatively few stations remain unvisited.

LAND METEOROLOGY OF THE BRITISH ISLES.—*The Quarterly Weather Report* for 1886 is in hand, and Part I. has appeared. *The Hourly Readings* for 1886 have been published. This latter volume will in future be materially altered, and instead of its containing the actual hourly measurements of the curves, &c., the hourly means of the different elements for 5-day and monthly periods will be printed. The wind will be given according to 4 components.

*The Harmonic Analysis* of the barograms for the 12 years ending 1882 has been completed, and the work is now being checked.

The volume of *Observations from Stations of the Second Order* for the year 1885 has appeared. That for 1886 is in the press. It will not be so large as its predecessors, as the number of stations from which the returns are published in detail has been reduced.

The printing of the *Observations from the Foreign Stations of the Royal Engineers and Army Medical Department* has now been completed, and the work will be issued about Easter. It forms a thick volume of 260 pages.

The observations from *Sanchez, Samana Bay, St. Domingo*, made by the late Dr. W. Reid, have now been printed, and the volume will shortly appear.

The tables for the Registrar General, Ireland, have been prepared in the office as usual.—*March 28th*, 1890.

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ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal; Departmental Superintendent, William Ellis, F.R.A.S.; Assistant, William C. Nash.—The instruments, observations and records made, and methods of reduction employed, during the year 1889 have been the same as in recent years.

The Thomson electrometer for indication of atmospheric electricity continued in an unsatisfactory state until the autumn of the year 1889, when it was readjusted by Mr. White of Glasgow, and again brought into use in the month of October. The scale is now larger than in the original state of the instrument.

In the spring of the year 1889 Mr. W. H. Dines very kindly tested our Robinson anemometer as well as a smaller instrument formerly used, on his whirling machine. These experiments showed that for high velocities the theoretical factor 3, used for converting the movement of the cups into wind velocity, is too large for both instruments, and that the registered velocities are therefore too great, as has been found for other similar instruments.

The publication of the volume for 1887 has been much delayed owing to the work incidental on the preparation of the Ten year Catalogue of 4,059 Stars. At the end of the Magnetical and Meteorological "Introduction" there will be found accounts of experiments made on days of extreme heat, bearing on the question of the effect of radiation from the ground and surrounding objects on thermometers. There is (1) a table of readings of the dry bulb and wet bulb thermometers on the ordinary revolving stand, with the circular board fixed below the thermometers, alternately removed and attached; (2) a table of readings of the dry bulb and wet bulb thermometers in the Stevenson screen, with the door (which fronts the white building of the magnetic observatory) alternately open and shut, with corresponding readings of the dry bulb and wet bulb thermometers on the revolving stand; and (3) a table of readings of the dry bulb thermometer of the new thermograph, with certain protecting radiation boards alternately removed and attached. These are followed by a table giving a comparison between results obtained from the old and new thermographs (both for dry bulb and wet bulb) on the days in the year 1886 when they were concurrently used, as well as a table giving, for the year 1886, June, to 1887, May, a comparison of the sunshine results obtained by the old Campbell form of instrument and the Campbell-Stokes modification of the same.

The "*Reduction of Twenty Years' Photographic Records of the Barometer and Dry Bulb and Wet Bulb Thermometers*," published in the year 1878, contained a reduction of the barometer records for the years 1854 to 1873, and of the thermometer records from 1849 to 1868. Commencing with the year 1877 results deduced from the hourly readings of the photographic records for barometer and thermometers have been printed regularly in the annual volumes of *Greenwich Observations*. In an appendix to the 1887 volume tables are given supplying corresponding results for the years 1874 to 1876 for the barometer, and for the years 1869 to 1876 for the thermometers, so that the reduction of the Greenwich Meteorological photographic records is now complete to the present time, commencing with the year 1854 for the barometer, and with the year 1849 for the thermometers.—*February 24th*, 1890.

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ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.A.S., Astronomer Royal for Scotland.

During the year 1889 the Meteorological Record at this Observatory has been limited to a single daily reading at 1 p.m. of the barometer and sundry

thermometers, together with the usual notes of wind and weather, including rainfall.

The four rock thermometers, with bulbs at various depths from 3 to 21 feet, have been read with all care every Monday as in former years.

Monthly digests, based on the bi-diurnal observations at eight principal towns in Scotland, and similar quarterly summaries derived from the records at all the fifty-five stations of the Scottish Meteorological Society, are drawn up at the Observatory and supplied to the Registrar-General for Scotland, by whom they are regularly published in the *Monthly* and *Quarterly Returns of the Births, Deaths and Marriages*. These summaries are supplemented by comparisons with the weather of former years, as well as by notes on current meteorological phenomena of special interest.—*January 17th*, 1890.

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THE KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.— G. M. Whipple, B.Sc., F.R.A.S., Superintendent.

The several self-recording instruments for the continuous registration respectively of atmospheric pressure, temperature, and humidity, wind (direction and velocity), bright sunshine, and rain have been maintained in regular operation throughout the year. The standard eye observations for the control of the automatic records have been duly registered, together with the daily observations in connection with the U.S. Signal Service synchronous system.

The tabulations of the meteorological traces have been regularly made, and these, as well as copies of the eye observations, with notes of weather, cloud and sunshine, have been transmitted to the Meteorological Office.

The readings of the old 100-inch area square rain gauge have been discontinued since February, the new 8-inch Glaisher gauge being now regularly employed, as a check upon the indications of the Beckley self-recording instrument.

The working standard barometer (Newman, 34) of the observatory, which has been in use continuously since the date of its erection about 1851, having become somewhat worn in its mechanism, was dismounted, and the scale and fittings repaired by Messrs. Negretti and Zambra, without interfering with the tube and cistern, which were retained at the Observatory. On its return it was again put together and restored to its old place, and fresh comparisons made with the Welsh absolute standards. These showed that a slight shift had taken place in the position of the zero of the scale, and a new determination of the scale error was made and fresh corrections accordingly adopted. During the period it was under repair the Royal Society's old standard barometer was used in the daily observations.

The barograph and thermograph formerly at work at the Armagh Observatory have been put in thorough repair, and set up in the Verification House awaiting the instructions of the Meteorological Council as to their transmission to the new Observatory under erection at Fort William, Inverness, at the base of Ben Nevis.

Tables of the monthly values of the rainfall and temperature have been regularly sent to the Meteorological Sub-Committee of the Croydon Microscopical and Natural History Club for publication in their *Proceedings*. Detailed information of all thunderstorms observed in the neighbourhood during the year has been forwarded to the Royal Meteorological Society soon after their occurrence.

The Electrograph has been in constant action throughout the year, and comparisons with the portable electrometer made in March, June, and September show the scale value to have remained unchanged.

The Committee have undertaken at the request of the Meteorological Council to make observations with a pair of Violle's actinometers. These consist of two delicate mercurial thermometers encased, the one in a well-blackened hollow metal sphere, the other in the centre of a similar sphere thickly gilded and having a highly polished surface. Being suitably mounted, they are taken out on sunny days, placed side by side in the open air, and exposed to the solar rays, until they attain the equilibrium temperature.

As it was found that a much more suitable site was offered by the roof of the new building for the working of the cloud cameras, the pedestal was removed from the position it formerly occupied and set up on gratings placed on the new

roof, the necessary alterations being effected in the electrical attachments. Opportunity was taken at the same time of replacing, by new wire, about 80 yards of the cable which had become damaged during the building operations. As, however, the question of the most convenient way of utilising the cloud pictures is still under consideration by the Meteorological Council, no photographs have been taken during the past year.

With a view of examining into the accuracy of the graduations of small anemometers or air-meters very much employed in measuring draughts and air-currents in mine-shafts, galleries, and similar places, a whirling apparatus was constructed and set up in the Optical Room, by means of which a number of experiments were made with Lowne's air-meters kindly lent by Mr. Casella, the maker, which afforded satisfactory results. The examination of these air-meters is now included in the list of operations carried on by the Verification Department.

The electrical anemograph, which was sent to Valencia in 1886 for erection on that island, was returned to Kew in a somewhat damaged condition after a lengthened trial in a very exposed situation. Certain defects in its construction which became evident during its stay there have now been corrected, and, after undergoing thorough repair, the instrument has been erected on a suitable staging on the roof of the Observatory, with the intention of submitting it to a comparison with the Beckley anemograph working at the same level about 14 feet due south of it.

In the Verification Department more than 14,000 instruments belonging to one or other of the twenty-eight different classes have undergone examination, and in the rating branch of the Observatory 528 watches have been submitted to the specified test.

A detailed list of all the operations carried on in the verification department, with the fees charged, &c. is in the press, and will shortly be issued in pamphlet form, price 3d.—*January 14th*, 1890.

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Radcliffe Observatory, Oxford.—E. J. Stone, M.A., F.R.S., Radcliffe Observer.—The following is a report on the meteorological work in this Observatory for the year 1889 :—

At the beginning of the year a change was made in the reckoning of the meteorological day. It had been usual in previous years to consider the day to run from noon to noon, but the hourly records now begin with the midnight values and end with those at 11 p.m., except the rainfall and anemometrical records, which include the results from midnight to midnight. The thermometers in the Stevenson screen are read at 8 a.m., noon, and 8 p.m. for the Meteorological Office ; the solar radiation and terrestrial radiation thermometers are read at 8 p.m. ; the Negretti anemometer, the rainfall, and the thermometers on the Tower are read about a quarter-past twelve (0¼ h. p.m.) ; and the rainfall in the 22 ft. gauge is measured at half-past twelve.

The instruments are in good order and working satisfactorily ; readings of the standard instruments are frequently taken during the day, and sometimes through the night, to check the scale of the photographic sheets.

The mean temperature of the air last year was 1°·0 below the average for the last 34 years ; the highest temperature was 79°·5 on July 30th, and the lowest was 19°·7 on January 6th and February 12th. There were 1,221 hours of bright sunshine registered during the year.

The eye-readings are reduced to the end of 1889. The *Meteorological Results* for 1886 are partly ready for press.

Dr. Haldane and Mr. M. S. Pembrey have made some interesting experiments, at the Observatory, on the moisture of the air, for a comparison with the results deduced from the dry-bulb and wet-bulb thermometers.

A meeting of the Midland Natural History Societies was held at Oxford on September 23rd and 24th, and a considerable number of the members visited the Observatory, which was opened to them in the afternoon of the 24th.—*March 22nd*, 1890.

CAMBRIDGE OBSERVATORY.—Prof. J. C. Adams, F.R.S.—The meteorological work at this Observatory has been carried on by Mr. H. Todd in the same manner as in former years. Daily telegrams and monthly reports are sent to the Meteorological Office.

No change has been made in the instruments, but the anemometer has been recording very badly, and a new one is about to be erected.—*January 14th*, 1890.

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# Observations on the Motion of Dust, as illustrative of the Circulation of the Atmosphere, and of the development of certain Cloud Forms.

BY HON. RALPH ABERCROMBY, F.R.Met.Soc.

[Received August 21st, 1889—Read February 19th, 1890.]

THE following observations have been made during many years past, with the exception of those on Whirlwinds, which were taken on various deserts on the west coast of South America, mostly in 1889, on the Tamarugal Pampa and on the desert of Atacama. The great value of the latter observations seems to be derived from the fact that in those dry districts we can note the forms in which grains of sand or dust of different weights and sizes arrange themselves when disturbed by air blowing in different kinds of ways; and thence deduce conclusions as to how large or small drops of water, or fine snowflakes, or coarse stones of hail, can be built up into certain cloud forms under the influence of gusts, or showers, or squalls of various types.

On any windy day we can see sand or leaves drawn out into streaks along the ground, and on any plain we can also see loose sand or dry snow formed into waves, whose troughs and crests are perpendicular to the direction of the wind. I have not succeeded in my endeavours to determine the conditions under which wind draws dust into lines parallel to itself, or builds the sand into billows at right angles to its own direction; but we see at once a striking analogy to two great types of cloud structure—the hairy or fibrous *cirrus* structure, whose filaments usually move in the direction of their length, and the fleecy *cirro-cumulus* structure, in which the cloud-bars frequently move at right angles to their length. The structure of *cirro-cumulus* can be reproduced with marvellous accuracy by giving a gentle oscillatory motion to a cylindrical bucket of water, on the bottom of which a little fine sand of suitable size has been sprinkled. The particles gather themselves up into a series of fleecy bars at right angles to the direction of oscillation, which exactly reproduce the appearance of fleecy clouds. Such conditions of oscillation cannot of course exist in nature; but the experiment shows by analogy that fleecy structure can be derived from the action of a current on a stratum of solid detached particles. When a fluid rubs against a flat solid surface, or

against a flat surface of a fluid different from itself, friction sets up a seri of friction rollers, as it were, or vortices with horizontal axes, which gath the sand or snow into lines parallel to themselves.

Under certain conditions wind does not blow a sandy plain into straig waves of sand, but into crescent-shaped heaps of a very singular charact which are called in Peru *mĕdănŏs*, or sand heaps. The general appearai of these will best be explained by glancing at Fig. 1, which was sketched fr nature on the Pampa de Joya, below Arequipa, in Peru. The crescent is to 20 feet high in the centre, and tapers down to nothing at the points of t

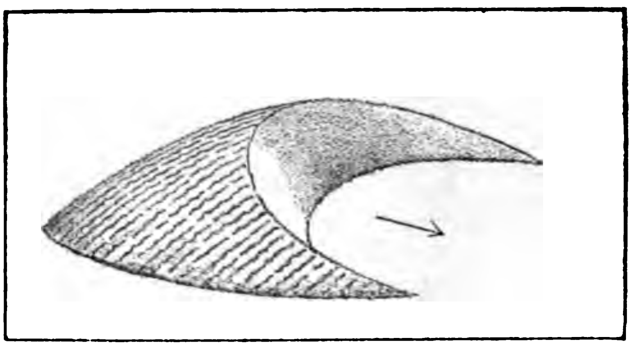

FIG. 1 MĔDANO OR SAND DRIFT ON THE PAMPA DE JOYA.

horns. The convex side of the whole faces the prevailing wind and prese a low angle of slope, while the inner surface of the crescent is as steep as sand will lie. The outer surface also, which faces the wind, is transvers furrowed into waves, as shown by wavy lines on the figure, so that there here a structure on a structure, exactly analogous to what is often seen cloud forms. The distance from the point of one horn to that of the ot will vary perhaps from 20 to 80 feet or more, and the whole advances slo before the wind, horns first. These *mĕdănŏs* are developed in great perl tion on the Pampa de Joya, where a whole plain, 30 miles across, is cove by these crescents of sand. I never saw a trace of this structure anywh on the Tamarugal Pampa, above Iquique, or on the Atacama Desert, thou the soil in both the latter districts is sufficiently light to be raised into wh winds of dust; but I think that the reason is to be found in the character the sand. The surface of the Pampa de Joya is covered with a sharp, lo volcanic sand mixed with but little dust; while the soil of the other Pam is more earthy and dusty, besides being more or less compacted with sa so that the difference in the form and structure of the wind-drifts must be to difference in the matter to be drifted.

On very rare occasions clouds of the cirro-cumulus type take a somew crescent-shaped form, as in certain examples of what are called "mack scales," and the ancient Norwegians had a cloud called *Nagelfar*, which supposed to be made up of parings of nails. I have no observations on

lie of these crescents relative to the motion of the cloud in which they are, but still I venture to put forward the suggestion that a stratum of cloud, composed of more or less crescent-shaped nubecules, may be formed by the action of wind on a floating layer of snow of some particular size or weight of flake.

We now come to a totally different type of air motion, in which dust is raised spirally, by a whirl round a more or less vertical axis. Those which I observed on the Atacama Desert were all of one type, in which the most violent whirl was on the surface, from which the dust seemed to be projected upwards either like a cloud or as a thin column, but this upper mass seemed to have very little rotation. The appearance at a distance was more like the smoke rising and diffusing into a thick mass above a small fire; rather than like the cylinders of whirling dust which have often been figured. Fig. 2 (A) represents the general impression of one of these whirlwinds, though the top of the sketch exaggerates the amount of rotation in the upper part of the whirl.

In another common variety, a small, intense whirl on the surface, seemed to puff a thin narrow column of dust high into the air, with very little appearance of rotation: see Fig. 2 (B).

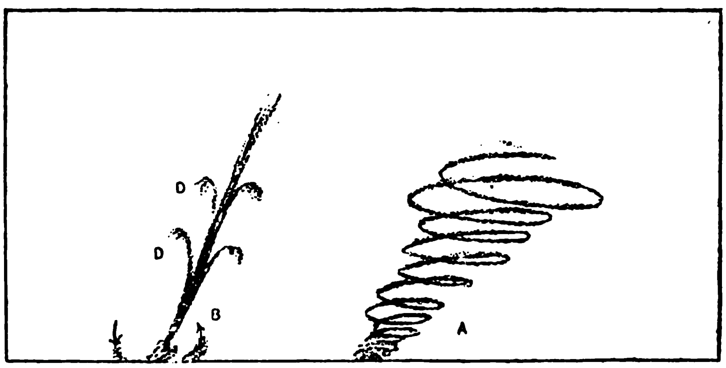


FIG 2 TYPICAL DUST WHIRLS TAMARUCAL PAMPA.

I was unable to determine whether the direction of rotation was always the same; but while endeavouring to make out the cycle of the whole circulatory system, I could sometimes see dust being thrown out, and falling downwards as in Fig. 2 (D). On the whole I think I must have observed nearly 100 whirlwinds, and in every case the central motion was upwards; but I should mention that I was informed that there was a district in Chili, somewhere between Atacama and Copiapo,—which I did not visit,—where the whirlwinds were descending. Whether this meant that the vortex of the whirl was really sucking downwards; or whether the idea was that the upward whirl commenced some distance from the ground and was then propagated downwards, I could not ascertain.

What I wish specially to remark is, that the whirls I saw on the Atacama Desert, starting from the surface, are not identical with the upward drawing

whirlwinds, which begin some height above the ground, and are propagated downwards. These latter are the variety of whirl which generates tornadoes and waterspouts: but which kind presents the greatest analogy to cyclones I cannot say.

As to whirlwinds with descending central vortices, though I have never seen one, I am by no means prepared to deny their existence, for many excellent observers have described such eddies.

For instance Mr. S. Elson, Pilot, of Calcutta, has not only described simple dust whirls near the ground of a descending type, but also a water-spout hanging from a cloud 500 or 600 feet above the earth. To him it seemed as if there was an upward whirl outside the black funnel of the spout, and simultaneously an inside down rush. [See *Calcutta Englishman*, September 13th, 1888.] If the spout and the dark cloud were represented by a sleeve hanging down from a jacket, the lining of the sleeve would be the downward current, and the outside cloth of the sleeve the violent uprush.

Dr. Vettin's experiments on smoke explain the mechanism of such an apparently contradictory circulatory system. If a column of air rises in a stationary medium, the fluid rushes in straight, or radially, to the centre, rises there and flows outwards radially above. But if a rotation is imposed on the system, the rarification of the central core seems to increase so much that air is sucked gently downwards from a stratum above the level of the upper outward current, or above the level of disturbance. The descending current seems to turn up sharply near the ground and join the upward outer current. The influence of rotation also turns both the ingoing and outgoing radial currents into spirally ingoing and outgoing streams respectively.

There is a very simple form of air motion which raises dust without any whirling. Any strong, straight blast of wind will raise a cloud of dust like that in Fig. 3, and the origin of the upward motion is very simple. If while a large body of air is in motion a thread of that air happens to move

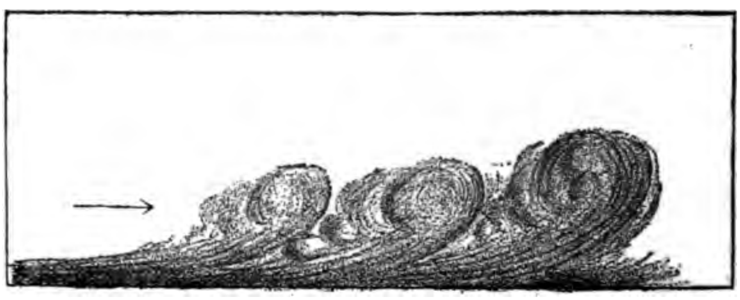

FIG. 3. SIMPLE CONDENSATION OF DUST

quicker than the adjoining portions, the gust so produced will catch up the air in front of itself, and, being pushed on from behind, will be forced to rise and carry some dust up with itself. If the air were laden with vapour instead of with dust, a cloud might be produced by condensation over the gust; and this I take to be the explanation of the simple cumulus cloud, without any

cirrification or any complex overlying stratum, which characterises the plain squall, unaccompanied by any shifting of the wind. It also explains what has long seemed puzzling, how cumulus-topped squalls could be formed with a North-west wind in rear of a cyclone, where the general body of air is probably slightly descending; for with the above conception there is no difficulty in the idea of the air rising locally over strong puffs of wind.

Between the simple rising gust and the whirlwind there seem to be various transitional types of air motion, and one which I was enabled to observe reproduces in an extraordinary manner some of the complex features of cloud building over certain kinds of showers or squalls. The dust-cloud represented in Fig. 4 was sketched on the Tamarugal Pampa, and though but a most imperfect delineation of the real thing, still reproduces the important features. A

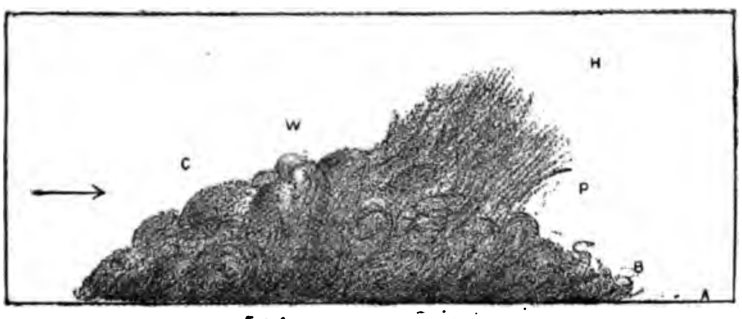


FIG. 4 COMPLICATED DUST WHIRL

dark base projects somewhat forward at B; above the mass again spreads outwards at P, but here the dust, instead of being either shapeless or of a rounded form, has a distinct tendency to be drawn into threads. The rear of the mass C is confused and rounded, and diffuses more gradually into the surrounding air than the front of the dust-cloud. The whole of the lower part of the mass was seething irregularly rather than appearing subject to any definite or distinct rotation, and sometimes a more pronounced rounded-topped column of dust would rise up angrily from the general mass for a few seconds, as at W.

Now compare this with some of the features of cloud-building over certain kinds of showers. In Figs. 5 and 6 are reproduced two diagrams of rain-clouds observed by myself on Lake Titicaca, in Peru. Premising that, on a large scale and with damp air, rain would be precipitated from such an atmospheric uptake as that represented in Fig. 4, the cumuliform lines of cloud C in Figs. 5 and 6 are analogous to the rounded dust forms (Fig. 4 B); while the white cirrifying cloud layers (W) in figs. 5 and 6 are represented by the thin hairy-like dust in Fig. 4 (P). It should be remarked that the clouds in 5 and 6 are viewed facing the direction of motion, while the dust-whirl (Fig. 4) is seen across the line of motion. An observer at A (Fig. 4) would see thin

fibrous dust (P) above a heavy-rolled mass of dust (B), just as in Figs. 5 and 6 I saw a white cirrifying cloud (W) above the dark cumuliform mass (C).

All the observations point to the following view of the origin of squalls—that when the air from general causes is in more or less rapid motion, small eddies of various kinds develop, which constitute the different sort of gusts, showers, squalls or whirlwinds.

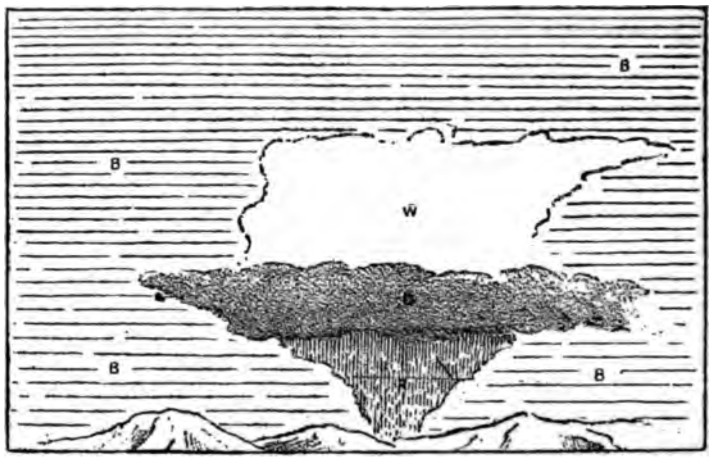


FIG. 5. B BLUE SKY: C FLAT-TOPPED MASS OF DARK CLOUD, ROUNDED COMPONENTS; R RAIN; W. WHITE CLOUD, TENDING TO FLATTEN OUT AND TO CIRRIFY.

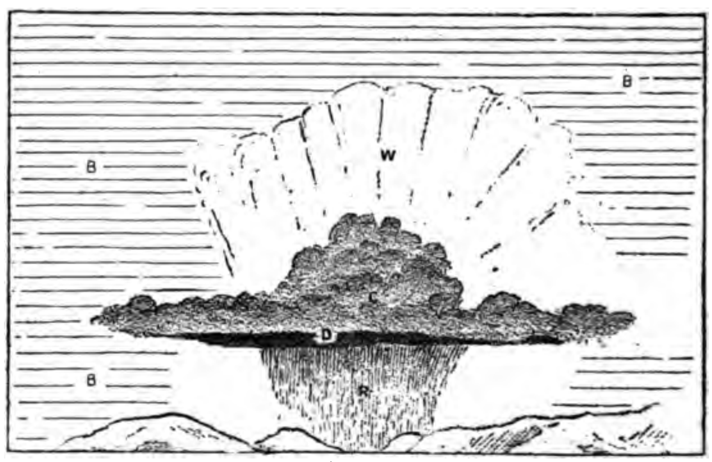


FIG 6 B BLUE SKY. C, DARK CUMULOFORM CLOUD, FLAT-TOPPED AT EDGES; D DARK BELT. R RAIN. W WHITE CLOUD, TENDING TO FLATTEN AND TO CIRRIFY.

I should like to notice a fact connected with the formation of dust whirls of all kinds, which was brought very forcibly to my notice in many localities. *Whirlwinds never formed till the afternoon wind sprang up.* All the intense insolation of the morning sun—I have recorded the temperature of the sand

at 180°—did not generate whirlwinds so long as the air was calm; and on any day the number of whirlwinds was about in proportion to the strength of the wind. I think this is very important in view of the numerous theories of whirlwinds, tornadoes and cyclones which have been propounded to explain these phenomena by reference to the rise of heated currents simply, without any reference to the general motion of the surrounding medium. The most intense heating, without sufficient wind, never gives rise to more than an intense rippling motion of the air, through which objects look wavy and indistinct, and never of itself induces whirlwinds.

The results of this paper may be summarised as follows:—

Wind sometimes blows dust into streaks or lines, which are analogous to fibrous or hairy cirrus clouds; sometimes into transverse ridges and furrows, like solid waves, which are analogous to certain kinds of fleecy cirro-cumulus cloud; sometimes into crescent-shaped heaps with their convex side to the wind, which are perhaps analogous to a rare cloud form called "mackerel scales;" sometimes into whirlwinds, of at least two, if not of three varieties, all of which present some analogies to atmospheric cyclones; sometimes into simple rising clouds, without any rotation, which are analogous to simple cumulus-topped squalls; and sometimes into forms intermediate between the whirlwind and the simple rising cloud, some of which reproduce in a remarkable manner the combination of rounded, flat, and hairy clouds that are built up over certain types of squalls and showers.

It is specially noted that excessive heating of the soil alone does not generate whirlwinds; but that they require a certain amount of wind from other causes to be moving at the time.

The general conclusion is, that when the air is in more or less rapid motion from cyclonic or other causes, small eddies of various kinds form themselves, and that they develop the different sorts of gusts, showers, squalls and whirlwinds.

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## DISCUSSION.

Mr. Blanford said that he did not quite follow Mr. Abercomby's analogy between the formation of sand-hills and of cumulus clouds. Fig. 1 represented very well what he had frequently seen on the sandy 'churs' of the Ganges (the dry flats in the bed of the river in the dry season), but there the dust was carried much higher than was shown in the illustrations, sometimes attaining an elevation of 500 or 600 feet. Mr. Abercromby had stated that "whirlwinds never formed till the afternoon wind sprang up." He did not question the accuracy of this statement, but as expressed it seemed to imply some confusion of cause and effect. Nothing was more common in India than to see small sand-whirls formed when the air was perfectly calm in hot weather. But where they are numerous, this indicates that convection was beginning to be active, and the ascension of air must be attended with an indraught of air from elsewhere to take the place of that which had ascended. He rather thought that the surface wind was the effect of the upward movement, and that the convection air-whirls and the surface breeze are merely two parts of the same general movement.

Capt. Maclear observed that the formation of shoals by currents of water carrying sand, as at river mouths, &c., resembled the mĕdăñōs, or crescent-shaped sand-hills, formed on the South American plains; the definition of the horns depending on the shorter duration of slack water, during which the deposit is

greater and more generally dispersed. As regarded the formation of cumulus cloud he remarked that he had seen this form of cloud produced over the dust and smoke from an Australian bush fire. He did not agree with the author of the paper that dust-whirls were never formed without wind, as he had often witnessed small dust whirls in the Australian bush when the air was perfectly calm. They usually formed quite suddenly on very hot days, and were of sufficient strength to carry hats and light articles up with them. It was, of course, possible that air currents existed higher in the atmosphere, but there was certainly no wind at the ground level.

Mr. HUTCHINS said that in Cape Colony he had seen dust-whirls formed in quite calm weather. These whirls occurred sometimes before noon, though more usually in the afternoon. Another point he had noticed, too, was that the motion of the particles of dust in the whirls was similar to the normal rotation of the wind in the Southern Hemisphere, *i.e.* clockwise and upwards.

Mr. LAWSON said, that in the sand-hills bordering Algoa Bay, at the Cape of Good Hope, there are considerable spaces where sand waves, with a gradual rise on the weather side of the crest and an abrupt fall beyond it, are caused by the prevailing winds at certain seasons. These crests are pretty straight, and frequently as much as half a mile in length, and there are a number of them following in succession; the sand is carried by the wind along the gradual rise to the crest, where it falls into the vacant space in front, filling it up and advancing the edge of the wave. A corresponding mode of transport may be observed in any ordinary ditch, in which there is a small stream of water over a sandy bottom. Regarding the time of occurrence of whirlwinds, he said he had seen one over the sea at Dover at 9 o'clock in the morning. In 1841, in passing through the North-east Trade to Barbadoes, he had often watched the commencement and increase of cumuli, but was unable to account for the peculiar rounded form they assumed until he witnessed the following occurrence. At Barbadoes he was placed in quarantine, in a small vessel, with some cases of measles; while there a soldier washed his belt in a bucket of fresh water, this, with a quantity of pipe-clay suspended in it rendering it quite opaque, he emptied over the side, the sea being perfectly smooth at the time; the pipe-clay water did not mix with the salt water for some time, but gradually subsided, pushing the salt water aside, and presenting the same rounded forms of surface which characterise the cumulus. Here the displacement of one fluid at rest by another took place downwards from the surface; in the case of the cloud the addition of vapour from below causes it to expand upwards, but the appearances, caused by its displacing the dry air around it, are manifestly to be explained in the same manner.

Dr. TRIPE drew attention to a sentence in which Mr. Abercromby said, "Wind sometimes blows dust into streaks or lines, which are analogous to fibrous or hairy cirrus clouds," and said he considered that there were two forms of hairy cirrus clouds, one only of which—the low form—was analogous to the lines of dust. The other form, high up in the atmosphere, does not appear to be produced in any way similarly to the lower form. He thought it desirable that this distinction should be made.

Dr. MARCET remarked that the formation of ripple-marks on a sandy beach at right angles to the direction of the wind was exactly similar to the ripples seen on the surface of a sea or a lake. The formation of ripple-marks by the deposit of particles suspended in water, subjected to a circular movement, and the occurrence of similar striæ on a viscous surface covered with water made to rotate, had been carefully investigated by M. Casimir de Candolle, who had suggested that cirrus clouds might be formed in a similar manner. Dr. Marcet had seen similar ripple-marks on the ice covering the summit of Mont Blanc. He then referred to a remarkable phenomenon described by Prof. Colladon, of Geneva, one of the Honorary Members of the Society, consisting in the upward motion of water particles on the outside of high waterfalls.

Mr. HARRIES wrote giving a reference to Professor Darwin's paper "On the Formation of Ripple-mark" in the *Proceedings of the Royal Society*, Vol. XXXVI. (1883) as bearing in many points on the subject dealt with by Mr. Abercromby. The paper is illustrated by a large number of diagrams, and the works of Mr. Hunt, MM. de Candolle, Forel, and others, in the same direction, are alluded to.

# CLOUD NOMENCLATURE.

By Capt. DAVID WILSON-BARKER, R.N.R., F.R.Met.Soc., F.R.G.S.

[Received December 9th, 1889.—Read February 19th, 1890.]

In the paper on "Cloud Observing," which I had the honour of reading before the Society in 1885,[1] I put forward a dual form of cloud nomenclature as a simple basis on which to found a more elaborate and scientific cloud system; and in fact any cloud classifier must recognise this basis.

In this paper I hope further to elaborate and explain my scheme with the aid of photographs.[2] No one will deny the necessity there is for more cloud observers, and that the observations should be followed on a more systematic plan than that now pursued. There are several cloud classifications put forward for adoption, some using one form, some another, to the total destruction of the value of cloud observation records in future years. In the majority of cases too much attention is paid to the particular form or shape of a cloud, and not enough to its physical structure and formation; as in former years too much attention was paid to the outward forms of animals, for instance a whale was called a fish because it was shaped like one and swam in the sea, etc. In reconsidering the nomenclature, we must consider not only the outward appearance, but more particularly the formation of clouds.

I by no means wish to say that my plan is the best for getting at what we want, but only place it before the Society as a contribution to the subject, having been a close observer of cloud and general weather phenomena in almost every part of the Ocean World during the last eleven years, under all possible conditions of weather and during all times of the day and night. I quite recognise the difficulty that attaches to any classification, particularly when one comes to deal with what may seem intermediate forms (but this is a common difficulty elsewhere, and we adopt a classification for simplicity), and for obvious reasons it is not only more convenient but almost absolutely necessary that we should have a basis to work on.

Vapour rising in the atmosphere, on condensing, tends to become visible in two ways, either in a globular or heapy form, or in layers or sheets. The former are cumulus (heap clouds), and the latter stratus (sheet clouds); all clouds will belong to either one form or the other, or will be transitory, and these latter we may refer to a sub-type.

It may be as well in the first place to define a cloud, "as vapour which has risen or descended in the atmosphere from a position having a temperature or density greater than the portion of the atmosphere it rises or descends to, which is then unable to retain it in its invisible form, and

[1] *Quarterly Journal*, Vol. XI. p. 119.

[2] The paper was illustrated by a number of lantern photographs, explaining the Author's proposed division of Cloud forms.

according to the physical state of the place it is attracted to, so will be the form it will assume on becoming condensed."

According to Mr. Aitken[1] no cloud can be formed unless there is a nucleus on which the vapour can condense, and so become visible. Then how are clouds formed at sea? is it possible that there can be dust over the ocean regions? I doubt it, unless in exceptional cases, and even then it seems difficult to imagine that clouds could assume all their varied shapes if they depended upon dust particles to make them become visible. Professor Tyndall aptly calls the minute particles of water vapour, which constitute a cloud, "water-dust." The well-known experiment of Tyndall's, whereby a brilliant cloud may be produced in a tube exhausted of its air by allowing humid air to enter suddenly, would certainly seem to disprove the dust-forming theory.

Before proceeding further it may not be out of place to give, in a few words, a history of cloud-nomenclature. Lamarck first in 1801 classified clouds, then in 1803 Luke Howard gave them seven names, viz., *cirrus*, *cirro-cumulus*, and *cirro-stratus* for high clouds, *cumulus*, *cumulo-stratus*, *stratus*, and *nimbus* for low clouds. This nomenclature is that practically used at present, and I have adopted it in describing my photographs; but however excellent it may have been at the time proposed, it does not come up to our present knowledge, and it is, therefore, desirable that steps should be taken to make some change in this matter.

Of all workers in this direction none have done more than the Rev. W. Clement Ley, and all cloud observers look forward to a monograph on this subject from him. This scientific division of the upper clouds is well known, but I think beginners would have some difficulty in learning the different forms unless first prepared in some way for it; the simple division here proposed would meet this difficulty. Besides Clement Ley, the Hon. Ralph Abercromby has proposed a system[2] embracing ten varieties, and nine sub-varieties; these are more or less modifications of Luke Howard's forms. Other well-known workers in this field are Poëy, Loomis, A. Mühry, Fitz-Roy, Mohn, Hildebrandsson, Weilbach, and others. Poëy has treated the clouds more fully than anyone since Luke Howard, and his book is well illustrated, though the pictures are sometimes rather fanciful and shaky in perspective. The great fault in all proposed classifications is that they do not meet either requirement, they are not simple enough for beginners, or complete enough—with the exception of Mr. Ley's—for skilled observers.

*Cumulus* may be defined as the cloud of the lower atmosphere, for although its tops reach great altitudes, yet its first appearance is in the lower regions of the atmosphere; it is also the variety of cloud which is chiefly formed in the rear of cyclonic disturbances, and may generally be considered to denote a state of disturbance—local or general—in the atmosphere. Frequently on the top of cumulus, increasing in size, and indicating considerable local

[1] *Transactions Roy. Soc. Edinburgh*, Vol. XXV., and elsewhere.

[2] *Weather*, by Hon. Ralph Abercromby, p. 119.

disturbance, will be formed little "cloud caps." It should be observed through all these photographs—though appearing under so many different forms and in places differing widely in geographical position—that they have yet a certain definite likeness to one another, and an observer could be quite safe in describing any one of them as a *cumulus.*

*Stratus* may be defined as the cloud chiefly of the middle and upper atmosphere; for although it frequently forms in the lower regions, yet it is much more common in the upper and middle parts. It is the cloud of fine settled weather, and also of the front portion of cyclonic disturbances. In the former case it appears either in broken patches, or else spreading all over the sky like a cloak, and having the appearance all round of being in lines parallel to the horizon. The sun shining through rifts in this cloud produces the well-known appearance called the "sun drawing water." As we get higher in the atmosphere it forms cirro-cumulus clouds, which clouds have an enormous range in altitude, appearing in the highest regions as the *cirro-granum* of Ley, and in the middle as the well-known mackerel sky; near the horizon it appears in the form of a thin sheet or layer.

Besides these I should like to call attention to a form of this cloud which I can only liken to the scales of a cycloidian fish in shape, and has a very thin texture; this cloud I have met with everywhere, and it invariably precedes or accompanies rainy weather; its motion is always very slow. I have never succeeded in getting a good photograph of it. All the forms of cirro-cumulus are really stratiform clouds. A very high stratus commonly accompanies very unsettled weather; it appears to consist of portions of cumulus (squall) cloud which are torn off and scattered all over the sky, often rising to great altitudes and forming delicate coronæ. It is most common on the fringes of squalls and showers, and during locally unsettled weather. It is a beautiful cloud, assuming the most wonderful and fantastic shapes, sometimes appearing in long strings and hanks, at other times like a lot of feathers, and again in wavelets.

Still higher in the atmosphere we come to the cirrus clouds, which are composed of minute ice crystals. With the true cirrus we include the cirro-stratus; but with this difference, that, while cirrus appears to be formed chiefly by ascending currents, the latter cloud will first appear as a cirrus and then slowly degrade into a cirro-stratus, later on into nimbus. Fig. 2 represents a vertical section of this cloud in the fore part of a cyclonic disturbance, where at A the cirro-stratus appears in lines; between A and B it is reticulated; at B halos become visible and the line structure disappears; and at C rain comes on: the cirro-stratus has then been propagated downwards until it fills the air to great depths and has become a nimbus. Fig. 1 shows the area over which the cirro-stratus is spread in a cyclonic disturbance. In squalls, we frequently have a great extension, in the rear of the squall cumulus, of the cirriform top, producing at times the appearance of a cirro-stratus cloud and even forming halos; it is seldom that there is any extension in front of the advancing squall.

I may here take the opportunity of mentioning a peculiar kind of haze

that at times fills the upper regions of the atmosphere, more especially in the centre of cyclonic disturbances, and in the rainy regions of the Tropics; it seems to be a kind of steamy stratus; but I am unable to account for it in a satisfactory manner.

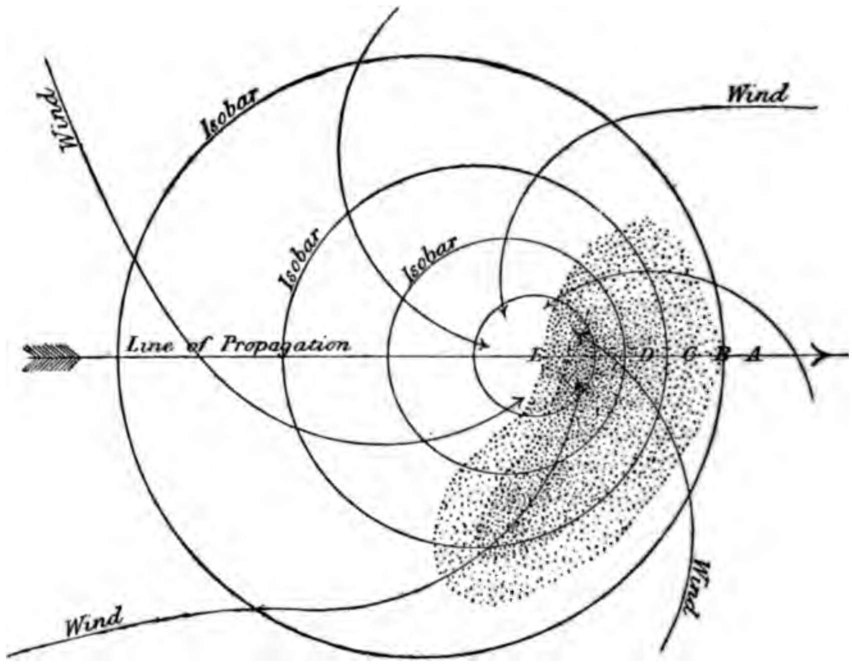


FIG. 1.

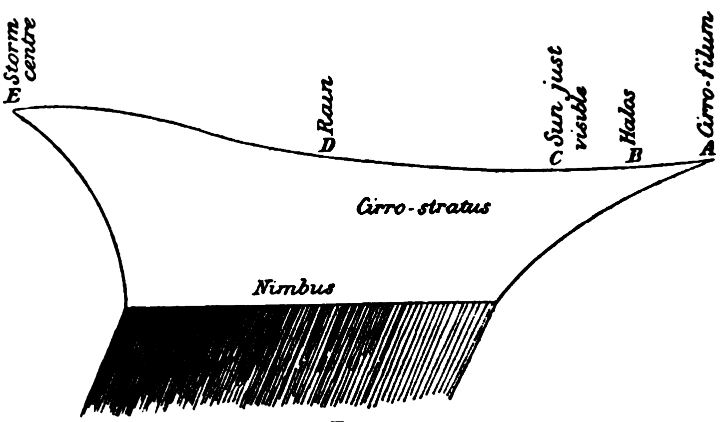


FIG. 2.

The heights to which clouds ascend will vary considerably all over the world, and will depend principally upon the temperature of the district. The actual altitudes are not of so great importance as the relative altitudes to one another.

Once an observer has thoroughly grasped the difference between these primary types, he will soon learn to distinguish the more minute divisions; and I propose "that a primary division of clouds should be arranged, taking the stratus and cumulus as main types, and that a more elaborate and complete division should be made of these two types."

In conclusion, I may state from experience that a good and complete collection of cloud photographs or pictures is indispensable for observers.

## DISCUSSION.

Mr. GASTER said that a vast amount of attention had recently been paid to photographs and pictures of clouds taken in various parts of the world, and much good work had been done by Mr. Abercomby, Dr. Hildebrandsson, and the author of the paper now read. But the great difficulty which arose in the question of cloud nomenclature, and which had not yet been met, was to devise such a classification that an observer could so describe the cloud he saw—that there would be no serious difficulty in deciding its form, and whether it belonged to the high, middle, or low level of the atmosphere. He had some time since attempted to prepare such a classification, based upon the old idea of four classes viz. cirriform, cumuliform, stratiform, and composite. With the result, however, he had never been satisfied, and after considering the matter further, he had come to the same conclusion as Captain Wilson-Barker had arrived at, *i.e.* that there were really only two primary forms, *cumulus* and *stratus*. He went on to show that in the upper stratum of the air, nothing but the stratus form is found, that nearer the earth the sheets of stratus grew thicker and their surfaces less well defined, while in the clouds observed near the earth's surface it was often difficult to say which were stratiform and which cumuliform. He entered upon a technical description of the various sub-divisions of the two primary heads, stating the distinguishing features peculiar to each, and concluded by promising to communicate a Paper to the Society, in which he would fully express his ideas on the whole question of cloud nomenclature.

Mr. ROTCH said that the subject of cloud classification had been very fully discussed at the International Meteorological Congress in Paris last September. Various schemes of classification were proposed, but it was the sense of the Congress that the nomenclature of Abercromby and Hildebrandsson, based on the division of Howard, was to be preferred, both on account of its simplicity, which was thought to be of importance for the majority of observers, and also on account of its already wide adoption by meteorologists. In regard to the pictorial representation of cloud types, it was pointed out that the natural colours were very important, but that all attempts hitherto made to reproduce them had been unsuccessful. The want had now been filled by the preparation of a Cloud Atlas by Hildebrandsson and Köppen, which was to be printed by chromo-lithography in Hamburg, and sold at the price of about twelve shillings a copy.

Mr. DINES wished to inquire whether there was any certainty about the height of clouds. He supposed that most observers formed a fairly correct estimate, but he wished to point out that in the vast majority of cases no possible means existed of knowing whether the estimate was right or wrong. He would explain what he meant by referring to those people who knew the direction of the wind by their feelings. They generally considered their feelings a better guide than a weathercock, but those who preferred the weathercock did not always agree with them as to the direction of the wind. Possibly the cloud observer might be in a similar position, and his estimates of height, if they could be checked, might also at times turn out to be wrong. Probably many persons had now and then seen a cloud, which they had considered the highest, pass across another cloud which they had previously thought to be the lower. He did not wish to imply that the estimates formed were wrong, but only that no means existed of knowing whether they were wrong, and hence he did not altogether agree with taking the height for the basis of cloud specification.

Capt. WILSON-BARKER, in reply, said that he found no more difficulty in determining the relative heights of clouds than in observing their motion. Of

course he did not pretend to be able to determine their actual elevation above the earth with any approach to accuracy; and he thought observers would find no difficulty in this matter, which was of great importance in his proposed primary division of the clouds.

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# AN OPTICAL FEATURE OF THE LIGHTNING FLASH.

By ERIC STUART BRUCE, M.A., F.R.Met.Soc.

[Received December 1st, 1889.—Read February 19th, 1890.]

In the First Report of the Thunderstorm Committee, which dealt with the photographs of lightning flashes, the Committee called attention to the fact "that there is not the slightest evidence in the photographs of lightning flashes of the angular zig-zag or forked forms commonly seen in pictures."[1] They also referred to the paper that Mr. James Nasmyth communicated to the British Association in 1856, in which Mr. Nasmyth says that a flash of lightning appears to him to be more correctly represented by an intensely crooked line, and he seems to doubt the existence of Artists' Lightning. To these apparently conclusive condemnations of the conventional idea of a lightning flash might be added the words of Mr. Ruskin in *Modern Painters*, when criticising Turner's "Stonehenge." He says:—"The white lightning, not as it is drawn by less observant or less capable painters in zig-zag fortifications, but in its own dreadful irregularities of streaming fire." It is noticeable that these words were written of Turner's picture many years before the publication of Nasmyth's paper.

But on the other side there was the evidence of one's own eyes, and those of many others, as having at times seen a zig-zag flash something very like the depiction of the artist, added to a conviction that in the conventional representation handed down from ancient times there is probably some element of truth.

From the time that the Royal Meteorological Society first exhibited its magnificent collection of photographs of lightning flashes I felt interested in the cause of the discrepancy, and gave the subject some thought and study.

Of one point I felt pretty sure,—that the photographs were a true representation of what exists in Nature (though possibly every kind of flash might not yet have been registered on the photographic plate). I was at first inclined to think that the effect of the angular zig-zag was due to an optical illusion, and I began to search for its cause in that class of phenomena that may be called "eye-sight illusions." While engaged in this search, it all at once occurred to me that I was on the wrong track, and that the explanation would be found not to be an optical illusion, but an optical

[1] *Quarterly Journal*, Vol. XIV. p. 229.

reality—not the flash itself, but the optically projected image of the flash formed on clouds. But why should the projection flash be in angular zig-zags? Because the clouds on which the projection is cast are often of the *cumulus* type, so as to afford an angular surface.

The image of the flash takes the angles of the uneven surface of the clouds. At this point let me make it quite clear that when I speak of zig-zag appearances, I do not mean that irregularity of the line of light that the flash of lightning and spark from an electric machine often displays, but only the long angles of the conventional representation. Having formed this theory in my mind, I proceeded to experiment, and succeeded in reproducing something very like the conventional lightning by casting the projection of a photograph of lightning on model clouds.

I have arranged on the table some model clouds presenting an angular surface.[1] In my lantern I have placed a photographic slide of a flash. It is of that type represented in the Report as "streaming." I have chosen that type, as it is without the irregularities of the other forms of flashes, being, to quote the description of it in Mr. Abercromby's report, "a plain, broad, rather smooth, streak of light." This flash, when projected on to the clouds, is to all appearances no longer a streaming flash, but is broken up into angles, and might be called a zig-zag flash.

Those who have knowledge of the laws of optics might endeavour to account for the projection of the image of a flash of lightning in more ways than one. I will now only point out one of the simplest ways in which it might occur.

Let the incandescent lamp represent a flash of lightning at some distance from the screen of clouds. When the light is flashed on and off, there is the simulation of sheet lightning on the cloud screen; now to transform the *sheet* lightning into *projection* lightning. To do this there must be an addition to the arrangements—a cloud with a small opening in it, somewhere between the flash and the surface of cloud upon which the projection is cast. Let a screen with one small opening represent such a cloud; when this is placed in position and the light flashed on, there is no longer the sheet lightning, but the image of the incandescent carbon—a distorted image as it falls upon the uneven surface of clouds. The sides of the horse-shoe of white hot carbon appear to be zig-zagged.

And now to go one step further. If we make another opening in the model cloud, there will be two images formed of the incandescent filament of carbon, and likewise in Nature a multiplication of openings will produce a multiplication of images of flashes. May this not explain the forked appearance so often depicted?

It may be objected that it seems inconceivable how this peculiar type of flash came to be regarded as the only type; for the image is probably not nearly so frequently seen as the flash itself. Perhaps the fact that the image of the lightning flash would not have that intense and dazzling brilliancy of the flash itself may explain this.

[1] These experiments were shown to the Meeting by the aid of the Optical Lantern.

If any brilliant source of light, such as the arc light, be suddenly flashed upon the average human eye, that organ would not recognise the form of the source; but if the image were flashed upon a screen, any eye would distinguish the image of the white hot carbon points, and so the projection would lose the bewildering brilliancy of the flash, and its distorted form would be impressed upon the mind. The diminution of brilliancy probably also explains that other objection—that no photographic plate seems to have yet registered the zig-zag "projection" flash.

DISCUSSION.

Mr. SYMONS said that, in common with all present, he felt much indebted to Mr. Bruce for the pains he had taken in investigating this question and the nicely arranged experiments which he had shown; but he did not feel convinced that the angular zig-zag flashes, represented in many pictures and engravings as repeatedly turning back at an angle of about 45°, actually existed. He considered that in a lightning flash we saw the actual electric discharge and not its projection on a cloud.

# PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

JANUARY 15TH, 1890.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

JAMES CLEMINSON, M.Inst.C.E., Villa Albano, Beulah Hill, Upper Norwood, S.E.;
WILLIAM JOSEPH HARRISON, Assoc.M.Inst.C.E., 7 Carteret Street, Queen Anne's Gate, S.W.;
DAVID ERNEST HUTCHINS, J.P., Knyosa, Cape Colony;
FRANCIS JOHN CHARLES MAY, Assoc.M.Inst.C.E., 25 Compton Avenue, Brighton;
LINDLEY WILLIAM POYNTER, M.Inst.C.E., 8 Marlborough Terrace, Worthing;
THOMAS ROBERTS, Assoc.M.Inst.C.E., Portmadoc, North Wales;
ROBERT ROBINSON, M.Inst.C.E., Beechwood, Darlington;
JAMES SHAND, M.Inst.C.E., Parkholme, Elm Park Gardens, S.W.;
JAMES ARTHUR FORREST DE VINE, The Cliff, Beccles;
ALBERT EDWARD WATSON, B.A., 7 St. John's Grove, Croydon; and
ROBERT GEORGE YOUNG, Assoc.M.Inst.C.E., County Asylum, Colney Hatch, N.,
were balloted for and duly elected Fellows of the Society.

JANUARY 15TH, 1890.

Annual General Meeting.

WILLIAM MARCET, M.D., F.R.S., President, in the Chair.

Mr. H. HARRIES and Mr. M. JACKSON were appointed Scutineers of the Ballot for Officers and Council.

Dr. TRIPE read the Report of the Council and the Balance Sheet for the past year. (p. 86.)

It was proposed by the PRESIDENT, seconded by Dr. TRIPE, and resolved :—"That the Report of the Council be received and adopted, and printed in the *Quarterly Journal.*"

It was proposed by Mr. BEAUFORT, seconded by Capt. MACLEAR, and resolved :—"That the best thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

It was proposed by Dr. LAWSON, seconded by Mr. TRIPP, and resolved :—"That the thanks of the Society be given to the Officers and other Members of the Council for their services during the past year."

It was proposed by Mr. STOKES, seconded by Mr. GWILLIAM, and resolved :—"That the thanks of the Society be given to the Standing Committees, and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

The PRESIDENT then delivered an Address on "Atmospheric Dust." (p. 73.)

It was proposed by Mr. BREWIN, seconded by Mr. ELLIS, and resolved :—"That the thanks of the Society be given to the President for his services during the past year, and for his Address, and that he be requested to allow it to be printed in the *Quarterly Journal.*"

The Scrutineers declared the following gentlemen to be the Officers and Council for the ensuing year, viz. :—

### President.

BALDWIN LATHAM, M.Inst.C.E., F.G.S.

### Vice-Presidents.

HENRY FRANCIS BLANFORD, F.R.S., F.G.S.
WILLIAM HENRY DINES, B.A.
CAPT. JOHN PEARSE MACLEAR, R.N.
WILLIAM MARCET, M.D., F.R.S., F.C.S.

### Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

### Trustees.

HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.
STEPHEN WILLIAM SILVER, F.R.G.S.

### Secretaries.

GEORGE JAMES SYMONS, F.R.S.
JOHN WILLIAM TRIPE, M.D., M.R.C.P.ED.

### Foreign Secretary.

ROBERT HENRY SCOTT, M.A., F.R.S., F.G.S.

### Council.

FRANCIS CAMPBELL BAYARD, LL.M.
WILLIAM MORRIS BEAUFORT, F.R.A.S., F.R.G.S.
ARTHUR BREWIN.
GEORGE CHATTERTON, M.A., M.Inst.C.E.
ARTHUR WILLIAM CLAYDEN, M.A., F.G.S.
WILLIAM ELLIS, F.R.A.S.
CHARLES HARDING.
RICHARD INWARDS, F.R.A.S.
EDWARD MAWLEY, F.R.H.S.
HENRY SOUTHALL.
WILLIAM BLOMEFIELD TRIPP, M.Inst.C.E.
CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P

FEBRUARY 19TH, 1890.

Ordinary Meeting.

WILLIAM MARCET, M.D., F.R.S., Vice-President, in the Chair.

OSWALD BRUCE CUVILJE, F.C.A., 68 Upper Berkeley Street, Portman Square, W.
WILLIAM HARPUR, M.Inst.C.E., 197 Severn Road, Cardiff; and
HENRY JOHN SPOONER, F.G.S., Assoc.M.Inst.C.E., 309 Regent Street, W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"OBSERVATIONS ON THE MOTION OF DUST, AS ILLUSTRATIVE OF THE CIRCULATION OF THE ATMOSPHERE, AND OF THE DEVELOPMENT OF CERTAIN CLOUD FORMS." By Hon. R. ABERCROMBY, F.R.Met.Soc. (p. 119.)

"CLOUD NOMENCLATURE." By Capt. D. WILSON-BARKER, F.R.Met.Soc. (p. 127.)

"AN OPTICAL FEATURE OF THE LIGHTNING FLASH." By E. S. BRUCE, M.A., F.R.Met.Soc. (p. 132.)

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## CORRESPONDENCE AND NOTES.

### ON THE RAINFALL OF THE RIVIERA.

Having found in M. Teisserenc de Bort's *Quinzaine Météorologique* 1877, page 179, abstracts of the observations made at Nice during the seven years 1870-76, I think that it will be well to convert his rainfall values and insert them in the *Quarterly Journal* as a supplement to my paper, in the last number, page 44.

Yearly total rainfall at Nice by M. Teysseire.

| | | Ins. | | | Ins. |
|---|---|---|---|---|---|
| 1870 | ... | 34·35 | 1874 | ... | 24·37 |
| 1871 | ... | 31·73 | 1875 | ... | 17·83 |
| 1872 | ... | 54·49 | 1876 | ... | 29·43 |
| 1873 | ... | 31·34 | | | |

Mean Yearly Total, 1870-76 ... 31·92 ins.

Mean monthly rainfall at Nice, 1870-76.

| | | Ins. | | | Ins. |
|---|---|---|---|---|---|
| January | ... | 3·06 | July | ... | ·61 |
| February | ... | 1·68 | August | ... | 1·03 |
| March | ... | 2·88 | September | ... | 1·22 |
| April | ... | 2·59 | October | ... | 6·03 |
| May | ... | 1·54 | November | ... | 5·03 |
| June | ... | 2·19 | December | ... | 4·06 |

G. J. SYMONS.

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### BUCHAN'S "REPORT ON ATMOSPHERIC CIRCULATION."

THIS forms one of the "Reports on the Scientific Results of the Voyage of H.M.S. *Challenger* during the years 1873-76." The work is really a re-discussion of all the available information regarding various atmospheric phenomena over the globe. The data are given in nine Tables of the Appendices, of which the more important are the mean diurnal variation of atmospheric pressure at 147 stations, the mean monthly and annual pressure of the atmosphere at 1,366 stations, and a similar table of temperature at 1,620 stations, and the mean monthly and annual direction of the wind at 746 stations.

The Report is divided into two parts, the first dealing with the diurnal

phenomena of meteorology over the ocean, and the second giving a comparative view of the climatology of the globe. The book extends to 842 pages of quarto letterpress, and is illustrated by 2 plates of diagrams and 52 coloured maps, showing the monthly and annual distribution of temperature and pressure of the atmosphere and winds over the globe.

The following is Mr. Buchan's summary of the distribution of the mean atmospheric temperature and pressure for the year:—

"The distribution of the mean annual pressure may be regarded as representing the sum of the influences at work, directly and indirectly, throughout the year, in increasing and diminishing atmospheric pressure and temperature.

"The isothermal of —5° surrounds the north pole, and marks off the region where the annual temperature of the globe falls to the minimum. The regions of highest mean annual temperature, marked off by the isothermal of 85°, occur in Central Africa, in India, the north of Australia and Central America; but, except Central Africa, these areas are very restricted. Temperature is depressed in the greatest degree towards the eastern sides of the land surfaces of the continents as they stretch towards and into the Arctic regions. As regards the ocean, temperatures are low on the eastern coasts of the continents of the northern hemisphere and on the western side of the continents of the southern hemisphere. The effect of the more clouded condition of the atmosphere of intertropical South America as compared with Central Africa is well illustrated by the isothermals of these two extensive regions.

"The most conspicuous example of the influence of ocean currents in raising the temperature is seen in the protrusion northwards of the isothermals over Western Europe, due to the prevailing winds and widespread currents which there pass from lower to higher latitudes. The contrast the temperature of the east coast of America offers to that of Europe is very striking. A similar result, but in a greatly reduced form, is seen on comparing the east of Asia with the west of North America.

"As respects land surfaces of tropical and sub-tropical countries, the highest mean annual temperatures are found in those regions where for a considerable portion of the year the climate is dry and practically rainless. The isothermals of Mexico and Brazil show in a striking manner the influence of dry and wet climates on the distribution of temperature in low latitudes. In this connection the crowding together of the isothermals in Africa and South America about latitude 30° S. is one of the most striking features of these lines.

"The chart of mean annual atmospheric pressure shows two regions of high pressure, the one north and the other south of the equator, which pass completely round the globe as broad belts of high pressure. The belt of high pressure in the southern hemisphere lies parallel to the equator, and is of tolerably uniform breadth throughout, widening, however, in the longitudes of the anticyclonic regions of the Pacific, Atlantic, and Indian Oceans, and of the less pronounced anticyclone of Australia. The belt of high pressure north of the equator has a very irregular outline, and exhibits the greatest differences as regards breadth and inclination to the equator. These irregularities wholly depend on the peculiar distribution of land and water which obtains in the northern hemisphere. The maximum breadth is reached over the continents of Asia and America; and, indeed, the area of high pressure may further be regarded as stretching across the Arctic region from the one continent to the other. The highest mean annual pressure, 30·20 ins., is attained in the anticyclonic region in the North Pacific. On the other hand, the belt of high pressure falls to the minimum in the Pacific immediately to the east of Japan, where it is less than 29·95 ins. It is also to be noted that pressure is nearly equally low in the east of the United States and parts of the Atlantic adjoining. About the same latitudes, both north and south of the equator, pressure is invariably high in the ocean a little to westward of all continents.

"These two belts of high pressure enclose between them the comparatively low pressure of equatorial regions, through the centre of which runs a narrower belt of still lower pressure, towards which the Trade winds on either side blow. This intertropical belt of low pressure exhibits several centres of still lower pressure. The most important and extensive of these includes India, the southern half of Arabia, and a large portion of Central Africa, where pressure falls below 29·80 ins.; and over a considerable part of north-eastern India it falls

under 29·75 ins. Over the larger proportion of the East India Islands pressure is also under 29·80 ins.; and there are besides two small regions near the mouth of the Amazon and near Panama where pressure does not quite reach 29·85 ins.

"Perhaps the most remarkable region of low pressure is in the Antarctic regions, which, remaining low throughout the year, plays the principal rôle in the wind systems bordering on and within the Antarctic Circle, with their heavy snows and rainfall, and in the enormous icebergs which form so striking a feature of the waters of the Southern Ocean. It is probable that over nearly the whole of the Antarctic regions mean pressure is at least less than 29·80 ins.

"In the north polar regions pressure is lower than over the continents, but higher than over the oceans immediately adjoining. In the temperate and Arctic regions there are two strongly marked depressions—the larger covering the northern portion of the Atlantic and adjoining lands, and the other the corresponding portion of the North Pacific, the mean in each falling in the centre below 29·70 ins.

"Now the whole of these areas of low pressure have the common characteristic of an excessive amount of moisture in the atmosphere. The Arctic and Antarctic zones of low pressure, and the equatorial belt of low pressure generally, are all but wholly occasioned by a comparatively large amount of vapour in the atmosphere. But as regards the region of low pressure in Southern Asia in summer, while the eastern half of the depression overspreading the valley of the Ganges has a moist atmosphere and a large rainfall, the western half of it is singularly dry and practically rainless, and its central portion occupies a region where at the time the climate is one of the driest and hottest found at any season anywhere on the globe. Hence, while observation shows the vapour to be the most important and widespread of the disturbing influences at work in the atmosphere, the temperature also plays no inconspicuous part directly in destroying the equilibrium of the atmosphere; from which disturbance result winds, storms, and many other atmospheric changes."

Mr. Buchan concludes as follows:—

"The Isobaric Maps show, in the clearest and most conclusive manner, that the distribution of the pressure of the earth's atmosphere is determined by the geographical distribution of land and water in their relations to the varying heat of the sun through the months of the year; and since the relative pressure determines the direction and force of the prevailing winds, and these in their turn the temperature, moisture, rainfall, and in a very great degree the surface currents of the ocean, it is evident that there is here a principle applicable not merely to the present state of the earth, but also to different distributions of land and water in past times."

## The Commencement of Meteorological Observations.

Dr. G. Hellmann, in an article on this subject in the monthly magazine, *Himmel und Erde*, puts the middle of the 17th century as the earliest date for systematic observations.

The earliest instrument was the weathercock. The first man to name the wind after the 4 cardinal points and their combinations was Eginhard, in the time of Charlemagne.

The Greeks erected the Temple of the Winds 100 B.C. with a Triton as vane on top. An actual cock, in metal, as a vane, was put on the church at Brixen in 820. Then followed Hooke's pendulum pressure plate, 1667.

The next instrument was the Hair, or rather Organic, Hygrometer, towards the end of the 15th century, probably due to Leonardo da Vinci. In 1665, Ferdinand II., the Grand Duke of Tuscany, used a "Mostra umidaria," consisting of a conical glass vessel filled with snow or ice. The moisture condensed on the outside of this was caught in a graduated glass measure. This was the first condensing hygrometer.

The Thermometer, as is well known, was invented by Galileo at the very beginning of the 17th century. The Rain-gauge by Padre Castelli about 1639, with the desire of ascertaining how much the surface of Lake Trasymene would be raised by a heavy fall of rain which had overtaken him after an inspection of the lake, then at a very low level.

The last instrument to be mentioned is the Barometer, and that invention of course was due to Torricelli in 1643.

# RECENT PUBLICATIONS.

American Meteorological Journal. A Monthly Review of Meteorology and Medical Climatology. Vol. VI. Nos. 9-11. January-March, 1890. 8vo.

The principal articles are:—The mathematical elements in the estimation of the Signal Service Reports: by W. S. Nichols (6 pp.).—State Tornado Charts: by Lieut. J. P. Finley (11 pp.). The States dealt with are Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.—Theory of storms, based on Redfield's laws: by M. Faye (21 pp.).—On globular lightning: by Dr. T. C. Mendenhall (10 pp.).—Diminution of temperature with height: by Prof. H. A. Hazen (8 pp.).—The International Meteorological Congress at Paris: by A. L. Rotch (18 pp.). This is an interesting and full account of the proceedings and papers read at the Congress held at Paris, on September 19th to 26th, 1889.—Spectre of the Brocken: by Prof. H. A. Hazen (4 pp.).

Charts showing the Normal Monthly Rainfall in the United States, with Notes and Tables. Prepared by H. H. C. Dunwoody, Capt., Signal Officer. 4to. 1889.

These Charts are based upon observations made at the stations of the Signal Service, Army Posts, &c. during the eighteen years, 1870-1888. The amount of precipitation varies from about 3 ins. in southern California, western Nevada, and western Arizona, to over 100 ins. in the extreme north-western portion of Washington Territory: the annnal rainfall at Neah Bay amounting to 105 ins There are two well-defined systems of precipitation within the limits of the United States; one practically covering that portion of the country east of the Rocky Mountains, and the other extending over the Pacific coast and plateau regions, although the rainfall in the southern plateau region is apparently not wholly within the western system, and the summer rainfalls in Arizona may result from the same causes which produce summer rains in New Mexico and Colorado. The vapour supply of the eastern system is evidently from the Gulf of Mexico and the Atlantic, and the thermal and wind conditions attendant over this area are such as to produce moderate rainfall throughout the year. As a general rule, the annual rainfall in the eastern portion of the United States decreases with the latitude, although the decrease is slight on the immediate coast. It also generally decreases with the distance from the source of supply of vapour. The annual rainfall exceeds 60 ins. on the central Gulf coast, near Cape Hatteras, and in north-east Georgia. It exceeds 50 ins. over the greater portion of the Gulf and south Atlantic, 40 ins. over the middle Atlantic and New England coasts and the greater portion of the Ohio valley, 30 ins. over the states east of the ninety-seventh meridian (excepting Minnesota), and 20 ins. in the region east of the one hundredth meridian. The precipitation occurring within this region is usually attendant upon the passage of areas of barometric depression, and the extent and amount of rainfall accompanying any particular storm depends largely upon the location and direction of movement of the centre of depression.

Beobachtungen der Meteorologischen Stationen im Königreich Bayern. Band. XI. Jahrgang 1889. 4to. 1890.

Contains: Bodentemperaturen an der K. Sternwarte bei München und der Zusammenhang ihrer Schwankungen mit den Witterungsverhältnissen: von Dr. K. Singer (24 pp.). This is a discussion of the observations of earth temperature instituted by Dr. von Lamont at Munich in 1860. The period dealt with is 25 years. The following are the principal results. The general means at the different depths are as follows:—

| | | |
|---|---|---|
| 1·3 metres | = | 48°·52 Fahr. |
| 2·5 „ | = | 48·48 |
| 3·6 „ | = | 48·41 |
| 4·8 „ | = | 48·41 |
| 6·0 „ | = | 48·31 |

The mean temperature at the depth of about 1 metre exceeds the mean air temperature by 1°·6, and these figures indicate the distinct influence of the elevation of the station above the sea. The epochs of the extremes and means are as follows:—At the upper station (1·8 metres) min. March 2nd, mean May 21st, max. August 24th, mean November 15th; each stage of descent of 1·2 metres produces a retardation of 21 days for the extremes, and 24 days for the means; and at the lowest station the order of the epochs is nearly exactly reversed, for we have min. May 23rd, mean August 24th max. November 17th, mean February 24th. The earth temperature at 1·8 metres between 1861 and 1889 has never fallen below 35°·6, and never risen above 62°·6; the extremes in the other strata have been successively 39°·2 and 57°·2; 41°·0 and 55°·4; 42°·8 and 53°·6; and 44°·6 and 51°·8. There is not space here to give all the conclusions of the author as to the relation of earth temperatures to weather, and we must refer to the original paper: but we should say that Dr. Singer finds that the amount of moisture exercises a decided influence on the ground temperature, a much heavier rainfall is required to produce effects of this nature in summer when the ground is covered by vegetation than in winter.

**Meteorologische Zeitschrift.** Redigirt von Dr. J. Hann und Dr. W. Köppen. January-March 1890. 4to.

Contains:—Die meteorologischen Ergebnisse der Lady Franklin Bay Expedition, 1881-83: von Dr. J. Hann (17 pp.). This is an elaborate summary of the scientific results of Gen. Greely's expedition, which are very creditable considering the frightful privations to which the staff were exposed, especially in the last winter.—Zur Frage der Sternenstrahlung: von Dr. J. Maurer (7 pp.). This is an inquiry into the question of what is the temperature of space, and whether any appreciable quantity of heat can reach the earth from the stars. The statement of Pouillet's that the temperature of space is —142° C has been generally accepted. Dr. Maurer gives as his own opinion, supported by Langley and Newcomb, that Pouillet's assertion rests on no solid foundation, and that any heat coming from the stars is quite inappreciable.—Die Theorie des ersten Purpurlichtes: von Dr. J. M. Pernter (10 pp.). This is an examination of the different explanations of the first purple glow, and Dr. Pernter concludes that Kiessling and Riggenbach have been right in attributing it to refraction.—Windstärke und Windgeschwindigkeit auf norwegischen Leuchtfeuer-Stationen: von Dr. H. Mohn (5 pp.). The stations use Wild's pendulum pressure plate anemometer, and when the more recent table of the velocities for each deviation of the plate is used the figures agree well with those given by the Wind Force Committtee of the Royal Meteorological Society.—Ueber atmosphärische Bewegungen: von H. von Helmholtz (4 pp.). This deals with the formation of wave motion, where two strata of different density are in immediate contact with each other, as air and water at the sea surface. The author seeks to explain the phenomena of atmospheric disturbances on this principle.—Resultate anemometrischer Beobachtungen auf der ungarischen Tiefebene in Kalocsa: von J. Fényi, S.J. (10 pp.). This is an examination of 6 years' records, in order to see whether Sprung's theory of the variation of wind direction in the daily period was correct for this station. The statement is: "In plains or on table lands the wind has a tendency to shift with watch hands in the forenoon, against them in the afternoon." The general result is satisfactory.

**Symons's Monthly Meteorological Magazine.** Nos. 288-290. January-March 1890. 8vo.

Contains among articles: The Eiffel Tower and its use (6 pp.).—Solar halos and parhelia on January 29th (3 pp.).—The Weather Plant (2 pp.).—Rainfall on Ben Nevis during January 1890, by R. C. Mossman.—Remarkably dry air, by Col. M. F. Ward (2 pp.). At Partenkirchen, Bavaria, on January 27th, at 2 p.m. the author recorded by his hair hygrometer the remarkably low relative humidity of 5; the dry and wet bulb thermometer readings also confirming this.—Meteorology in Roumania (3 pp.).—The March frost (2 pp.).—"Areas of rarefaction" or "depressions," by Rev. G. T. Ryves (1 p.).

# QUARTERLY JOURNAL

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## A BRIEF NOTICE RESPECTING PHOTOGRAPHY IN RELATION TO METEOROLOGICAL WORK.


By G. M. WHIPPLE, B.Sc., F.R.A.S., F.R.Met.Soc.,

Superintendent of the Kew Observatory of the Royal Society.



[Read March 19th, 1890.]


ALTHOUGH most of the Fellows of the Royal Meteorological Society have been aware, that for many years past photography has been a valued handmaid to the Meteorologist, in relieving him in a great measure from the labour entailed in taking numerous and frequent observations of thermometers, the barometer, and other necessary instruments, yet comparatively few persons are acquainted with the details of the apparatus or methods employed.

Having prepared for another purpose a set of lantern transparencies of the instruments in use at the Kew Observatory, and at many of the other Meteorological observatories both at home and abroad, the Council of this Society have thought it might offer some interest to the Fellows to exhibit these photographs to this meeting. I have also prepared some notes as to the history of the application of photography to the purpose of continuous

registration, which, I think, may be of importance in throwing light upon the question of priority of the invention, a matter which, so far as I am aware, has not been fully treated of in any text-book of Meteorology.

The prosecution of the study of weather and its changes entails frequent and numerous observations of the various natural phenomena which in the aggregate go to make up what we term "Weather," and which popularly may be described as changes in the various properties of the aerial ocean which surrounds us, and at the bottom of which we live. These phenomena are its temperature; its humidity or extent of dryness, *i.e.* the amount of aqueous vapour it holds in suspension; its motions; its density and also its electrical condition. Variations in its chemical constitution and in the number or nature of the objects accidentally floating in it, such as dust organic or inorganic, including germs and seeds, although of great interest to the naturalist and sanitarian, are scarcely to be considered as falling within the scope of the science of Meteorology as understood at the present time. It is to be hoped, however, that as we obtain a fuller knowledge of many of the phenomena first mentioned, those later named may come in for more extended notice.

With regard to the question of priority of discovery of photographic registration, I do not wish to be unjust to any person who may be entitled to the credit of being earliest in the field, more especially to any foreigner who may have published suggestions as to the feasibility of this method, but I desire to refer in this paper only to those gentlemen whom I have been able to find as distinctly having removed the invention from the region of conjecture to that of actual *performance*.

In the extreme south-west of England there has existed for 56 years a comparatively small scientific and artistic society—the Royal Cornwall Polytechnic Society, founded by some young ladies in 1833—which publishes annually an 8vo volume of *Proceedings* of about 200 pp.

In 1838 its Secretary, Mr. T. B. Jordan, who was also a mathematical and philosophical instrument maker, in Falmouth, described an instrument for recording by means of photography the variations in the height of the barometer by passing light through the Torricellian vacuum and allowing the top of the mercurial column to arrest the luminous rays in their passage to sensitized paper. Mr. Jordan also devised a recording declination magnetograph, and a self-recording actinometer, all of which instruments with engraved illustrations are described in the Sixth Annual Report of the Polytechnic Society.

The next application of photography, in the order of time, was by Sir Francis Ronalds, at that time Honorary Superintendent of the Kew Observatory, who in 1840 was hard at work on atmospheric electricity. Having constructed an apparatus which he called an electrograph, he obtained a record of the times at which electrical tension caused sparks to pass from a conductor electrified by the air to an earth wire, in the following ingenious manner:—A metal disc covered with sealing-wax was substituted for the hand of a clock, and carried round on its upturned dial, beneath a finger

connected by a wire with a collecting mast. As sparks passed from the conductor on the mast to the ground they heated and softened the sealing-wax on the disc, so that on powdered chalk being shaken over it Lichtenberger's figures were formed, which were retained in the wax when it cooled. Ronalds had these discs placed in front of an ordinary camera, and photographed by Mr. Collen, of Somerset Street, London, a photographer he called in for the purpose. This somewhat roundabout process was soon after modified into one of moving a sensitized photographic plate slowly in front of a pair of electrified gold leaves of a Bohnenberger's electroscope, and recording the amount of their divergence under different electrical conditions.

Next come the simultaneous labours of Brooke and Ronalds, the results of the incentive of grants made by the Royal Society for the successful construction of self-registering instruments. Full accounts of both gentlemen's work will be found in the *Philosophical Transactions* for 1847, and the principal parts of their original apparatus are now to be seen in the Loan Collection of Scientific Apparatus, at the South Kensington Museum.

Since the time of Brooke and Ronalds their magnetographs and meteorographs have undergone many modifications in detail, but not in principle; it is not necessary now to go into these, we shall therefore proceed to other instruments since constructed.

The thermograph and pluviograph are both derived from the barograph; the earth current recorder and Thomson electrograph are both adaptations of Gauss's mirror method, as used by Brooke in the Greenwich magnetograph. The Jordan sunshine recorder, in which the method of producing records is characterised by extreme simplicity, is a descendant of T. B. Jordan's heliograph of 1838. Finally we must mention Roscoe's recording actinometer, and Abney's cloud cameras, as the latest achievements we can consider at present.

I now propose to exhibit on the screen the lantern slides that I have prepared from actual examples of the various instruments enumerated already, which are now in daily work at the Kew Observatory and elsewhere; they are as follows:—

1. Beckley's modification of the Jordan-Ronalds barograph (diagram and instrument).
2. Beckley and Stewart's modification of the Brooke-Airy thermograph (diagram and instrument).
3. Welsh and Beckley's improved Gauss-Brooke magnetographs (diagram and instrument).
    *a*. The declination magnetometer.
    *b*. Bifilar or horizontal force magnetometer.
    *c*. Balance or vertical force magnetometer.
4. Thomson electrograph (diagram and instrument).
5. Jordan's form of sunshine recorder.
6. Whipple's modified Abney's photo-nephograph.

We shall now proceed to consider the various photographic processes which have been employed in connection with the above instruments. To the best

of my belief the process first used for recording on paper (that adopted by Jordan) was Fox Talbot's, and known as the Talbotype, but on account of the sluggishness of the photographic action of this process and its inability to record rapid movements of the magnets, as well as of the supposed irregularity in the traces produced by the warping and shrinkage of paper in the drying and other operations, Ronalds employed the Daguerreotype process for his instruments, which entailed the subsequent copying of the traces for the purpose of preservation by hand on gelatine sheets. The outlines of the curves were traced over by means of an etching point, then ink was rolled over them as in copper-plate printing, and afterwards impressions were worked off for distribution.

The process used by Mr. Brooke, and subsequently by Mr. Glaisher, at the Royal Observatory, Greenwich, was a modified Talbotype process, and is described at length in the introduction to the annual volumes of *Magnetic and Meteorological Observations* made at the Greenwich Observatory.

The Radcliffe Observatory at Oxford, being provided with a Ronalds barograph, early abandoned the use of the Daguerreotype plate in favour of Le Gray's waxed paper process as improved by Mr. Crookes, and these methods were adopted by the Kew Committee, when continuous registration of the magnetic elements was entered upon, at their Observatory, in 1857.

The waxing and ironing of the sheets of Canson's paper was an operation which consumed a great deal of time, but in 1859 this part of the work was much facilitated by Messrs. de la Rue & Co., who undertook the hot-pressing and cutting the paper by means of machinery. The staff at Kew prepared the paper for pressing by arranging it in piles made up of sheets dipped in melted refined white wax, alternating with plain sheets and blotting-paper in a certain order, beforehand. In 1867, the Meteorological Office established their system of seven British Observatories, all working with the Kew pattern instruments and using the same photographic process, and soon after a number of foreign Observatories were also organised, using both magnetographs and meteorographs, all of which came to Kew for their supplies. Messrs. de la Rue found the claims on their good nature too heavy, and were compelled to withdraw their assistance, and so recourse was had to a manufacturer of waxed paper, Mr. John Sanford, who supplied it in considerable quantities, ready prepared for use, until a recent date.

The instability of the silver compound in the sensitized sheets rendered waxed paper extremely subject to change, and any variations in the temperature or humidity of the air might bring about great discoloration of the exposed sheets, frequently causing the partial and occasionally the total loss of the curves. Hence it was a welcome fact to learn that all the requirements of self-recording instruments were met by the use of gelatinized bromide paper. This could be purchased in the market in adequate quantities ready to be wrapped around the cylinders without occupying time in preparatory processes, and could be dealt with subsequently by very easy

methods, not liable to the annoying mischances incidental to development by gallic acid.

Since 1882 Greenwich and Kew, with all its affiliated Observatories, with I think only two exceptions, have entirely abandoned the old or waxed paper for the gelatinized or A.G.B. paper prepared by Messrs. Morgan & Kidd.

This paper, however, has two rather serious drawbacks. The first is the unequal shrinkage of the film and paper, producing distortion in the curves which is considerably greater than that found to exist in the case of waxed paper. The other defect is the curling up of the paper in drying. This, at first, was a serious inconvenience in the operations of measuring and tabulating the curves, but is now of little note, care being taken to avoid unnecessary exposure to either sun-light or heat.

Eastman's paper is, I believe, used similarly in America, and Huntinet's on the Continent, but, so far as I am aware, neither are employed in this country.

We now proceed to consider the sunshine recorder. Mr. James B. Jordan's sunshine recorder records the varying intensities of sunshine by varying the amount of discoloration produced in a paper sensitized by the ferro-cyanide process. A strip of prepared paper is put into a brass box, and the sun's light allowed to pass through a small slit in the side of the box, and fall upon the paper; after the day's exposure, the paper is fixed by immersion in clear water, and we have then upon its surface a blue trace, the intensity of which roughly measures the amount of solar influence upon the earth. As now constructed, a pair of hemi-cylindrical boxes are fixed back to back upon a frame which can be placed parallel to the Equator at the station.

The next and most recently-designed photographic meteorological instrument we would refer to is the photo-nephograph or cloud camera, an apparatus not yet fully developed. Its object is to obtain simultaneous instantaneous photographs of the same cloud from two or three stations situated at a distance from half-a-mile or upwards from each other. These simultaneous pictures are then used for determining the positions of clouds above the surface of the earth, and so obtaining a knowledge of the upper currents of the air, their direction and motion at heights far above those at which anemometers can be placed, and in places where they may be supposed to be unaffected by the irregularities and eddies formed by unevennesses, such as hills and valleys, which modify the contour of the earth's surface.

At Kew, two cameras fitted to theodolites are erected on stands half-a-mile apart, but electrically connected by an underground telegraph wire. Each camera is provided with an adjustable instantaneous shutter, which can be manipulated by an electric current at the will of the directing operator. The *modus operandi* is as follows:—A first points his camera at a selected cloud, and then having instructed the observer at the remote station B, through a telephone, as to the direction in which he should place his instrument, releases both shutters at the same instant of time, so obtaining a pair of pictures in which the stereoscopic effect affords the required data.

The plates exposed are slow gelatine plates, prepared according to a

formula devised by Captain Abney, to whom also most of the details of the arrangement of the instrument are due. After development by pyrogallic acid and fixing, proofs are printed on albumenized or gelatinized paper, from which, subsequently, measurements are made of the photographs, which supply material for the computation of the cloud positions and motions, whilst at the same time valuable information is also given as to structural changes continually in progress in the clouds.

With regard to the utilisation of the photograms given by the recording instruments, suffice it to say that various processes of photographic reproduction by photo-engraving, photo-lithography, &c., have been tried as well as mechanical reproduction by pantagraphs; but for practical use it has been found best to convert the curves into numbers by methods of tabulation, and then distribute the results to the public as printed columns of figures.

The following is an alphabetical list of the names of the principal Observatories at home and abroad, where photographically recording meteorological or magnetical apparatus is known by the author to be in action at the present date:—

*Great Britain and Ireland.*—Aberdeen, Falmouth, Glasgow, Greenwich, Kew, Oxford, Stonyhurst, Valencia.

*Colonial.*—Adelaide, Alipore, Bombay, Hong Kong, Mauritius, Melbourne, Sydney, Toronto.

*Foreign.*—Batavia, Brussels, Coimbra, San Fernando, Lisbon, Lyons, Madrid, Nantes, Nice, Paris, Perpignan, St. Petersburg, Utrecht, Vienna, Washington, Wilhelmshafen, Zi-ka-Wei.

The lantern slides exhibited have been made, under the author's direction, by Mr. W. Hugo, photographic assistant at the Kew Observatory.

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# APPLICATION OF PHOTOGRAPHY TO METEOROLOGICAL PHENOMENA.

## An Address delivered to the Royal Meteorological Society, March 19th, 1890.

By WILLIAM MARRIOTT, F.R.Met.Soc.,
Assistant Secretary.

Mr. Whipple has described the various methods adopted for obtaining meteorological records by means of Photography. My subject, viz. Meteorological Phenomena, has a much wider range, and I hope to show how photography can be most usefully employed for the advancement of meteorological phenomena.

I have made a large number of Lantern Slides from photographs of various meteorological phenomena, which I shall now throw on the screen.

These slides are largely illustrative of the present Exhibition, as they have been mostly taken from objects exhibited in the other room.

CLOUDS.

*Slide 1.* Typical Cloud Forms, by Hon. R. Abercromby. (*Quarterly Journal*, Vol. XIII. Plate 8.)

*Slide 2.* Cumulus Cloud, taken by Mons. Paul Garnier at Boulogne-sur-Seine, France.

This slide and Nos. 4 and 5 were taken from a magnificent set of large photographs of clouds sent by Mons. Garnier to the Exhibition. They are the best photographs of clouds that have been seen in this country.

*Slide 3.* Shower Cumulus Cloud, by Mr. A. W. Clayden.

The measurements were :—

| | |
|---|---|
| Height of base ... ... | 2,500 feet. |
| Thickness ... ... ... | 4,200 ,, |

A rather heavy shower of cool rain was falling from the cloud.

*Slide 4.* Cirro-Cumulus Cloud, by Mons. P. Garnier.

*Slide 5.* Cirrus Cloud, by Mons. P. Garnier.

*Slide 6.* Cirrus Cloud, by Mr. A. W. Clayden.

*Slide 7.* The same, taken 10 minutes later.

*Slide 8.* Cirrus Cloud reflected from the surface of the Lake of Sarnen, August 1888, by Dr. A. Riggenbach.

There has been some difficulty in getting good photographs of the highest forms of cloud, owing to the fact that the blue light of the sky acts with nearly the same actinic energy on the sensitive plate as the white light of the clouds. Dr. Riggenbach, of Basle, in a paper read before this Society in November 1888, said :—"If any plan could be devised for dulling this blue light of the sky while the light of the clouds was left unaffected, the clouds would stand out from the comparatively dark background of the sky in the photographic picture, just as they do in the images formed by our eyes." He explains how the analyser of any polarising apparatus will effect this object; and then goes on to say :—"A still simpler mode of obtaining such cloud-pictures is to use the surface of a lake as a polarising mirror. The best clouds for such a purpose are those at sunrise or sunset, at an altitude of about 37°, and in an azimuth either greater or less than that of the sun by 90°. In the photographs exhibited it will be seen that the clouds are especially clear in the reflection; but the coast lines also come out with unusual distinctness, much clearer than in the direct view, owing to the extinction of the sky light."

LIGHTNING.

On several occasions papers have been read at the Meetings of the Royal Meteorological Society describing various forms of lightning, and special interest has always been attached to the accounts of "ball" or "globular" lightning. This form of lightning appears as a ball or globe of fire, varying in apparent size from a cricket-ball to a football; it moves

slowly—in fact, some people have stated that they have been able to get out of its way—and, as a rule, it finally explodes with great violence. As several persons doubted the existence of ball and some other forms of lightning, the Council considered that much valuable information might be obtained from photographs of flashes of lightning. In response to the Council's appeal in 1887 a large number of such photographs have been sent in to the Society, from which it is evident that lightning does not take the angular zig-zag path so frequently seen in artists' pictures, but pursues a sinuous and very erratic course.

*Slide 9.* Typical forms of Lightning Flashes. (*Quarterly Journal*, Vol. XIV. Plate 3.)

The Thunderstorm Committee in their Report on these photographs have attempted a classification of the various forms of lightning flashes. The following are some of the most typical forms :—

1. Stream Lightning, or a plain, broad, rather smooth streak of light.

2. Sinuous Lightning, when the flash keeps in some one general direction, but the line is sinuous, bending from side to side in a very irregular manner. This is the commonest type of lightning.

3. Ramified Lightning, in which part of the flash appears to branch off from the main streak, like the fibres from the root of a tree. There is no evidence as to whether these fibres branch off from, or run into, the main flash.

4. Meandering Lightning. Sometimes the flash appears to meander about in the air without any definite course, and forms small irregular loops. The thickness of the same flash may also vary considerably in different parts of its course.

5. Beaded or chapletted Lightning. Sometimes a series of bright beads appear in the general white streak of lightning on the photographic print. These brighter spots occasionally appear to coincide with beads in the meandering type, but often the beads appear without any evident looping of the flash. It is probable that these brighter spots may be points where the flash was moving either directly towards or away from the camera, and thereby giving a somewhat longer exposure to these spots.

*Slide 10.* Ramified Lightning, by Mr. A. H. Binden, Wakefield, Mass. U.S.A.

*Slide 11.* Lightning on September 2nd, 1889, by Mr. H. J. Adams, Beckenham.

*Slide 12.* Lightning at Sea, taken at Hong Kong.

The Committee also described another type, viz. Ribbon Lightning. Some of the photographs show flashes exhibiting more or less of a ribbon-like form. One edge of the ribbon is usually much whiter and firmer than the other. This is produced by optical causes near the edge of the plate, where the pencil of light from the lens falls obliquely and the sensitive film is either beyond or within the focus. The section of the pencil of light is then not circular, but usually consists of a bright point with a nebulous tail, causing a hazy edge to the bright image of the flash. This ribbon character

is not continued all across the plate, but the breadth of the flash and its hazy edgings vary with the distance from the centre of the plate.

*Slide 13.* Photograph showing Flash with a curtain of light, taken by Mr. E. S. Shepherd, August 17th, 1887.

Some of the photographs showed flashes like a broad band or curtain of light. Several suggestions were made as to the probable cause of this duplication, but the Committee deemed it prudent not to express an opinion on the point. The grand display of Lightning which occurred on June 6th, 1889, afforded an opportunity for photographs to be taken, which have, I think, practically settled this question. Wherever this anomaly occurred, it has been ascertained that in each case the camera was either held in the hand or was not securely fixed.

*Slide 14.* Photograph showing four parallel flashes of Lightning, June 6th, 1889, by Mr. G. J. Ninnies.

*Slide 15.* Photograph showing three series of three similar parallel flashes of Lightning which took place while the camera was being swayed to and fro, by Dr. Hoffert, on June 6th, 1889.

The very interesting photographs obtained by Mr. Ninnies, at Balham, and Dr. Hoffert, Ealing, seem to lead to the conclusion that a lightning flash is not instantaneous, but has a much longer duration than has generally been supposed to be the case.

*Slide 16.* Dark Flash, by Mr. Shepherd.

On one of the photographs taken by Mr. Shepherd, on August 17th, 1887, there was the anomalous appearance of a *dark* flash of lightning. There was a good deal of speculation as to its cause, but the theories advanced were not satisfactory.

*Slide 17.* Dark Flashes, by Rev. A. Rose.

Three or four photographs showing dark flashes were obtained during the storm on June 6th, 1889, the most notable being those taken by the Rev. A. Rose, at Emanuel College, Cambridge, and by Mr. Clayden, at Tulse Hill.

*Slide 18.* Photographs of electric sparks explaining the formation of dark images of Lightning flashes, by Mr. A. W. Clayden.

Mr. Clayden has since made a number of experiments in photographing the sparks from an electric machine, which tend to show that the dark flashes are due to photographic reversal. Among the experiments were the following: 1. Sparks photographed in a dark room. No reversal. 2. Plate exposed to diffused daylight after exposure to the sparks. Partial or complete reversal. 3. Small sparks allowed to impress images on the plate, one-half of which was then exposed to gaslight. Complete reversal. 4. Plate exposed to diffused gaslight *after* exposure to the sparks. Reversal. 5. Plate exposed to diffused gaslight *before* exposure to the sparks. No reversal.

Mr. Shelford Bidwell has also made experiments in photographing electric sparks, and has obtained results which confirm Mr. Clayden's explanation of the dark images of lightning flashes.

### Effects of Lightning.

*Slide 19.* Tree shivered by Lightning at Audley End.

*Slide 20.* A man's clothes torn off his body by Lightning on June 8th, 1878, while standing under a tree, near Ashford. (*Transactions of the Clinical Society of London*, Vol. XIII. p. 32.)

*Slide 21.* Clothes of two men who were struck by Lightning at Spaniard's Farm, Hampstead Heath, June 14th, 1888.

*Slide 22.* Photograph of one of the men injured at Spaniard's Farm, showing the scars on the arm and other parts of the body.

*Slide 23.* Arm of a boy struck by Lightning at Dunse, Berwickshire, June 9th, 1883, showing arborescent or tree-like markings.

The boy, who was thirteen years of age, had sought shelter with three other boys in a stable when the occurrence took place; he was thrown to the ground and hurt about his face and forehead by the fall. His father, who is a chemist, writes:—

"The motion of the arms was for some while completely paralysed, inasmuch as he was unable, until some considerable time after regaining consciousness, to remove his hands from his pockets, where he had placed them before the accident. There was also in the arms a sensation of numbness and cold, and he fancied that they had been broken at the elbows. Other voluntary movements were at first inaccurate and unsteady. Later, upon his complaining of a burning heat in the arms his coat was removed, and markings of an arborescent character were discovered stretching from below the left elbow to the shoulder, and throwing branches of a less complicated character across the left chest. The marks were of a ramified, tree-like form, and seemed to radiate from two centres, as if the lightning had first struck the arm in two places, and had thence broken over the surrounding skin. Shortly after the accident the boy walked home without assistance, and on his arrival the marks were subjected to a closer inspection. They proved of a red colour, somewhat similar in shape to that of the spots of measles or scarlet fever. The surface of the skin was slightly raised over them, and the superficial heat of the injured arm was greater than that of the rest of the body. For two hours after the stroke they retained their original appearance, remaining to the naked eye at least perfectly unaltered. By 7.30 p.m., eight and a half hours after the accident, they were hardly visible, and at ten o'clock next morning had entirely disappeared."

## Tornadoes.

*Slide 24.* Two views showing the devastation caused by the Tornado at Rochester, Minnesota, U.S.A., on August 21st, 1883.

*Slide 25.* Ditto.

The great force of the wind in the Tornado was illustrated in a very striking manner by these two views, as one showed a horse impaled by a large branch of a tree; and the other showed pieces of straw driven *end-on* into the bark of trees.

*Slide 26.* Tornado Cloud taken at Jamestown, Dakota, U.S.A., June 6th, 1887. Two views. The cloud funnel was 12 miles to the north.

*Slides 27-30.* Damage by the Tornado which passed across the Isle of Wight from Brightstone to Cowes, between 7 and 8 a.m., September 28th, 1876.

An ordinary rapidly revolving whirlwind, looking like a waterspout, or a huge funnel, point downwards, came on the South-west shore of the Isle of Wight, about half-way between Black Gang Chine and the

Needles. The same, or another, passed north-eastwards over Cowes, causing by its updraught great wreckage in the town, carrying off corn, light articles, and even bricks, dropping some on vessels in the Solent, and carrying some north-eastwards on to the mainland south of Titchfield. The damage at Cowes by the whirlwind was estimated at £10,000 or £12,000.

## Floods.

*Slide 31.* Railway Bridge between Bransford and Henwick destroyed by the flood on the Teme, May 14th, 1886.

*Slide 32.* River Severn at Worcester in flood, May 15th, 1886.

Rain commenced falling about noon on Tuesday May 11th over the Midland Counties of England, and continued, but with increasing intensity, till Friday morning; the duration at most places being about 60, and in some places nearly 70, hours. The heaviest fall occurred in Shropshire, where during the three days more than 6 inches fell at several stations, and at Burwarton as much as 7·09 ins. was recorded. At Church Stretton 4·12 ins. fell on the 13th.

The waters of the Severn and Teme continued to rise until 1 a.m. on Saturday, when they reached a point higher than any flood since 1770. About mid-day on Friday 14th, the railway bridge over the Teme between Bransford and Henwick gave way in consequence of the flooding of the river. The centre pier collapsed, and although the railway metals remained, they sank down with the structure, and the line became impassable.

*Slide 33.* Flood at Rotherham Railway Station, May 15th, 1886.

*Slide 34.* Flood at Hereford, Midland Railway Station.

*Slide 35.* Flood at Bristol, March 9th, 1889.

The rainfall was continuous during the 34 hours preceding midnight on March 8th, and during the interval the depth measured reached 2·91 ins. There had been a heavy snow storm throughout Monday, March 4th, which covered the ground to the depth of 6 ins.; and the thaw which occurred on the 5th and 6th served to intensify the effect of the heavy rain which fell on succeeding days. Disastrous floods resulted. At Bristol the loss was estimated at £100,000.

## Frost, &c.

*Slides 36 and 37.* Hardrow Scar Waterfall. Two views: first, Summer flow; second, Winter view, January 25th, 1881.

On January 25th the cone at the bottom was a mass of frozen spray, firm to walk upon, but a stick could be pushed down into it. The cone was about 30 feet high. The upper part was a hollow icicle, semi-transparent, down the centre of which the water could be seen falling and passing into the cone below, which was opaque.

*Slide 38.* Niagara in winter.

*Slides 39, 40 and 41.* One view showing the Observatory on Ben Nevis in summer, and two views, in winter, when the Observatory was completely covered in snow and hoar-frost.

*Slide 42.* Icicles near Aysgarth, Middle Force, February 10th, 1887. By Rev. F. W. Stow.

*Slide 43.* Thick rime on trees at Lincoln, January 7th, 1889.

*Slide 44.* Models of Hail stones seven inches in circumference which fell near Montereau, France, on August 15th, 1888. (*Quarterly Journal*, Vol. XV. p. 47.)

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# THE COLD PERIOD AT THE BEGINNING OF MARCH, 1890.

By CHARLES HARDING, F.R.Met.Soc.

[Read April 16th, 1890.]

This paper has been undertaken at the wish of the Council, and the short time which has been at my disposal for its preparation, will, I hope, secure your indulgence, and will sufficiently explain the crude manner in which the somewhat extensive observations have been thrown together.

The discussion is limited to England, as both Ireland and Scotland escaped almost entirely the cold snap which is dealt with in the paper.

The cold was very intense over the whole Continent of Europe during the early days of March.

On March 1st, an anticyclone which had prevailed over the whole of the British Islands for some days suddenly gave way, and a small area of low barometer readings was situated off the East of England, the barometer being below 29·9 ins. This disturbance travelled to the southward and caused a considerable fall of snow in many parts of England, and especially in the South-eastern districts.

After the passage of this disturbance the barometer recovered considerably, and an anticyclonic area embraced the whole of England. This area gradually moved southward, and was situated to the south of England after the 4th.

On the 4th, when the cold was most intense over England, and especially over the southern portion, the air was very still, much of the country being situated between the influence of the anticyclone in the South and the cyclonic circulation in the North and West.

The subdivisions followed by the Meteorological Office have been adhered to, since that grouping collects the observations into reasonably large areas.

The districts dealt with are:—

| | | |
|---|---|---|
| 1. England NE. | ... ... ... | 12 Stations. |
| 2. England NW. | ... ... ... | 15 " |
| 3. Midland Counties | ... ... | 27 " |
| 4. England E. | ... ... ... | 13 " |
| 5. England S. | ... ... ... | 51 " |
| 6. England SW. | .. ... ... | 23 " |

On March 1st, the minimum temperature fell below the freezing point at every station in the North-east of England; the lowest reading was 24°·3 at Driffield. The maximum readings were also low, Shields being the only station at which the thermometer exceeded 40°.

In the North-west of England the minima were not quite as low as in the North-eastern district, but the thermometer fell below the freezing point at all except the coast stations.

In the Midland Counties the minima were uniformly below the freezing point except at Wakefield, where the thermometer registered 32°; the lowest reading in the whole district was 22°·5 at Cheltenham. The maxima were all below 40° except at Stokesay, Burghill, Hereford and Ross, all situated in the South-western margin of the district, and at most of these stations the thermometer rose to 45°.

In the East of England the minima are shown to be still lower, the thermometer reading 20° at Somerleyton, and at several stations, both on the sea coast and inland, registering 23° and 24°. The maxima were generally only 2° or 3° above the freezing point, except at Hitchin.

In the South of England the minimum ranged from 20° at Brockham to 30° at Totland Bay, Isle of Wight, but the average reading was 25° or 26°. Gosport and Ventnor were the only two places at which the maximum thermometer exceeded 40°.

In the South-west of England the readings were much more variable, but with the exceptions of the stations in the extreme West, the minimum thermometer fell below the freezing point. The maximum thermometer was, however, uniformly above 40°.

On the 2nd, the minimum temperature fell below the freezing point at all stations in the North-east of England except Shields, where it registered 32° only. At Alnwick Castle the reading was 20°. The maximum readings were much lower than on the previous day, and were the lowest of any of the first five days. The highest temperature was 36°, recorded at both Shields and York, whilst at Spurn Head and Lincoln the temperature did not rise above the freezing point throughout the day.

In the North-west of England the minima were lower than on the 1st. At Kirkham the temperature fell to 19°, which was the lowest recorded during the cold spell, but at all other stations the minima occurred on the 3rd or 4th.

In the Midland Counties the thermometer generally fell lower than on the previous day, but the difference was not very great. The lowest reading was 21°·2 at Buxton, where the elevation is nearly 1,000 ft. At Berkhamsted Mr. Mawley registered 21°·2, and at Churchstoke the reading was 21°·5. The maximum temperatures nowhere reached 40°, but with the exception of Harrogate, Buxton, Belper, and Stamford, the thermometer rose above the freezing point during the day.

In the East of England the minimum readings were generally much lower than on the previous day except in the Northern part of the district. The lowest temperature was 18° at Hitchin, and at both Royston and Cambridge the reading was 19°. At several stations the thermometer did not rise above the freezing point throughout the day.

The frost was severe over the whole of the South of England, but the thermometer did not register a lower reading than 20° at any station. The maximum temperature scarcely anywhere exceeded the freezing point by more than 1° or 2°, and at many places it froze all day.

In the South-west of England the minima were not generally much lower than on the 1st; a frost, however, occurred at all stations, but in the Channel Islands and at Scilly the thermometer did not fall below 35°. The maximum readings were, however, lower than on the previous day, and everywhere below 40° except at Weston-super-Mare.

On the 3rd, the cold was more severe at nearly every station in the North-east of England; the lowest temperature was 18°·6 at Driffield, but the next lowest was 22°·5 at Rounton.

In the North-west of England the minima were also nearly everywhere lower than on the previous day, and at most of the Northern stations, and at Liverpool and Macclesfield, the lowest temperature of the period occurred on this day, and at several of the coast stations the thermometer fell lower than at any time in the previous winter.

In the Midland Counties the minima were everywhere lower than on the 1st or 2nd, except at Churchstoke and Cheltenham, and at all stations in the district the thermometer registered below 25°. At Harrogate, which is the most Northern station, the lowest temperature of the cold spell occurred on this day. The lowest readings were 13°·5 at Buxton, 18° at Aspley Guise, and 18°·8 at Berkhamsted.

In the East of England the frost was more severe than on the 1st or 2nd, except at Yarmouth and Lowestoft. The lowest readings were 11° at Hillington, 14°·5 at Hitchin, and 15° at Cambridge.

In the South of England the temperature was everywhere lower than on the two previous days. At Chatham, Maidstone, Crowborough, Brighton, and Ventnor, the lowest temperature during the cold snap occurred on this day, and the readings were lower than at any time during the previous winter. At Maidstone the thermometer registered 10°, at Chatham 15°, and at Crowborough 15°·8. At several stations the maximum during the day did not reach the freezing point; among these were Margate, Hastings, Brighton and Rousdon, whilst at Ventnor the highest reading was only 32°·4.

In the South-west of England the minima were everywhere lower than on the 1st or 2nd. At St. David's and Pembroke the lowest reading was registered on this day, and the temperature was lower than at any time during the winter. At Guernsey the maximum during the day was 32°·9, and at Jersey 33°.

The Diagram (Fig. 1) for March 3rd shows that the minimum was below the freezing point over the whole of England, as well as at Scilly and the Channel Islands. The coldest areas were in the Eastern parts of England and at Buxton. By far the largest part of England had a temperature between 20° and 25°, whilst there were only a few stations on or near the coasts with readings above 25°.

On the 4th, the temperature in the North-east of England was nearly

everywhere the coldest of the spell, and at some stations the temperature was lower than at any time during the winter. At Driffield the thermometer registered 14°·5, and at Lincoln 19°·8. The maxima were, however, higher than on the three preceding days, except at Appleby, where the reading on the 1st was nearly 1° warmer.

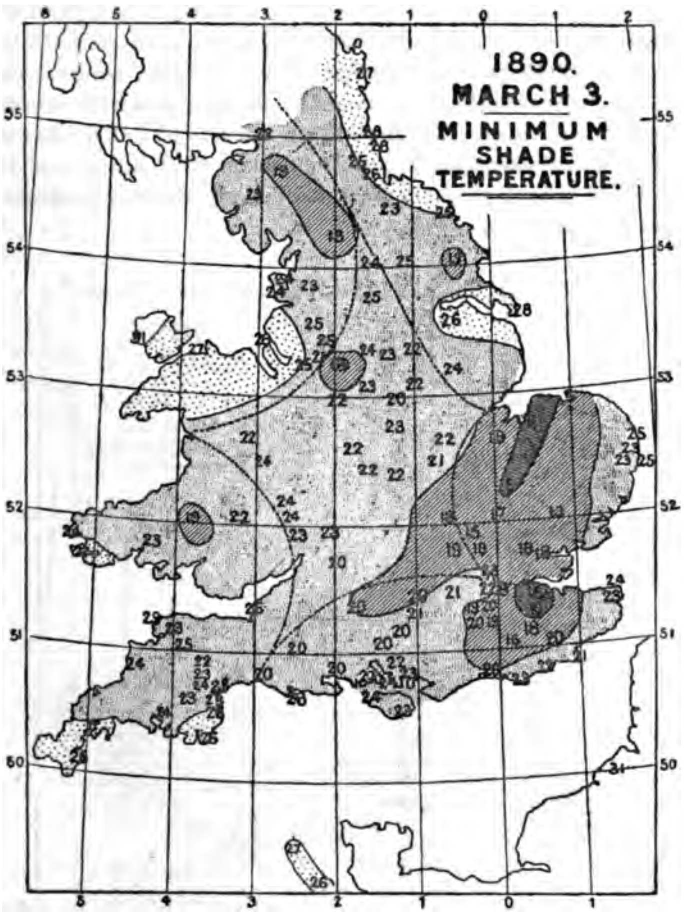


FIG. 1.

In the North-west of England the lowest temperatures for the period were generally observed on the 4th in the Southern part of the district, but a general rise had commenced in the North. The maxima were several degrees warmer than on the preceding days.

In the Midland Counties the minimum for the period occurred on this day except at Harrogate, in the extreme North, which was warmer than the 3rd by 0°·5. At very many stations, especially in the South, the temperature was lower than at any time during the winter. The lowest readings were 10°·9

at Buxton, 12° at Stamford, 13°·8 at Berkhamsted, 14°·9 at Gloucester, 15° at Cirencester, and 15°·2 at Hereford and Cheltenham. A very marked rise was generally shown in the maximum readings.

In the East of England the minimum on this date was everywhere lower than any recorded during the past winter, at least wherever observations have been made. The lowest readings were 6° at Hillington, 6°·8 at Chelmsford, and 11°·2 at Rothamsted. The minimum was nowhere above 22°, and with the exception of Yarmouth and Lowestoft, nowhere exceeded 15°·3.

In the South of England the minima almost uniformly occurred on this day, and with but one or two exceptions the temperatures were lower than any during the past winter. The lowest readings were 5°·4 at Beddington, 6° at Kenley, 7°·3 at Beckenham, 8°·5 at Addiscombe, 9° at Reigate and Brockham, and 10° at several places in Kent and Surrey, whilst at Greenwich the thermometer fell to 13°·1.

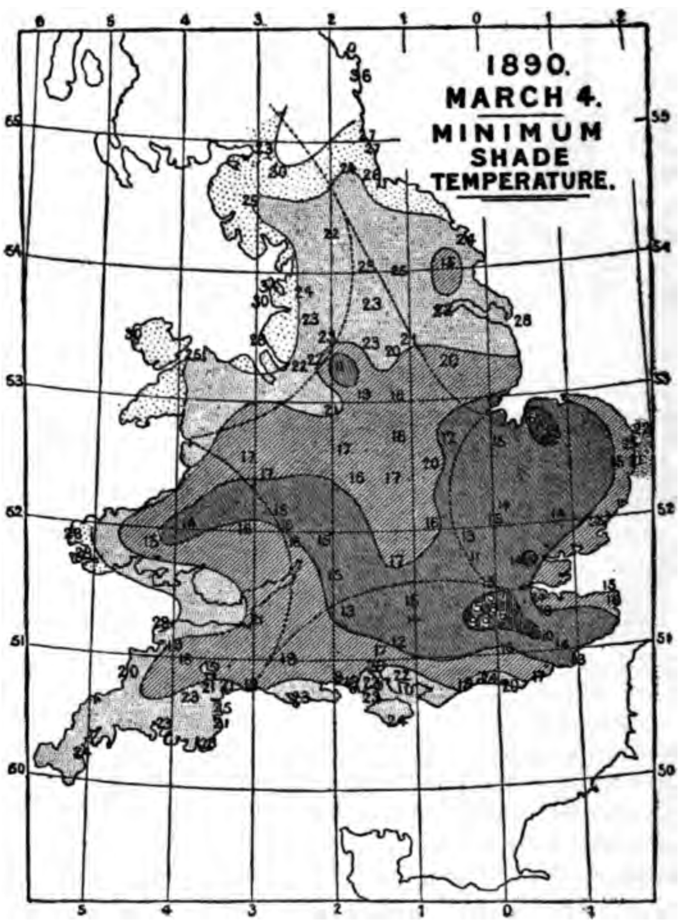


FIG. 2.

In the South-west of England the minima were very low, and wherever the test could be applied the readings were lower than at any time during the winter. The lowest readings were 14° at Llandovery, 14°·8 at Cullompton, 15° at Carmarthen, 15°·5 at Castle Hill, South Molton, and 15°·8 at Gwernyfed Park, whilst in Jersey the thermometer fell to 21°.

The Diagram (Fig. 2) for the 4th shows that the greatest area of cold was situated over Kent and Surrey, whilst equally low readings were recorded at isolated stations in Essex and Norfolk. Temperatures of 15° or below were registered over nearly the whole of the East of England, the Southern Midlands, and in part of the South-western district. The temperatures are seen to be uniformly lower over the Midland, Eastern, Southern, and South-western districts, the readings above 20° being now almost entirely limited to the coast stations, or to the North of England. Some increase of temperature is shown in the North, but Alnwick Castle is the only station over the whole of England (comprising as well Scilly and the Channel Islands) where the minimum reading was above 32°.

On the 5th, a considerable rise of temperature took place over the North-east of England, and frost occurred only at stations in the southern part of the district, whilst the maximum temperature everywhere ranged between 45° and 49°.

In the North-west of England frost only occurred at a very few stations, and the maxima ranged between 45° and 48°.

In the Midland Counties frost was much more general, but very many of the readings entered to the 5th really belong to the 4th, and are due to the practice of reading the thermometers in the morning only. The maxima ranged from 43° at Bawtry to 50°·8 at Ross.

In the East of England frost was general but not at all severe, whilst the maxima ranged from 39°·4 at Hitchin to 47° at several stations.

In the South of England a slight frost was also experienced, and the maxima were generally between 42° and 52°.

In the South-west of England a similar increase of temperature was shown, the thermometer during the day nearly reaching 50° at many stations.

The following remarks show the localities in which the frost was exceptionally severe, and it is hoped will afford data for comparison with other low temperatures which may be hereafter experienced. The observations for the districts England NE and England NW do not call for any special remark, lower readings being frequently observed at this season of the year.

### MIDLAND COUNTIES.

HARROGATE.—Min. 24°·3. The thermometer registered 18° on January 3rd.

WAKEFIELD.—Min. 23°·2. 19°·2 was recorded on January 3rd; which is 4° lower than on March 3rd. Several lower readings observed in March during the last 15 years, and lower winter temperatures very frequent.

HODSOCK.—Min. 19°·7. The lowest winter temperature was 19°·6 on December 29th. Was lower in March in 5 years during the last 15 years; the lowest being 5°·3 on March 10th, 1883; and each year has had a lower winter temperature except 1881-2, and 1883-4. The absolutely lowest reading was —5°·8 on December 7th, 1879.

## TABLE I.

Shade Temperatures observed from March 1st to 5th, 1890.

The Minimum Temperatures printed in italics are the lowest recorded during the Winter of 1889–90.

| Stations. | 1. | | 2. | | 3. | | 4. | | 5. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Min. | Date. |
| 1. England N.E. | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Alnwick Castle | 37 | 30 | 35 | 20 | 38 | 27 | 45 | 36 | 47 | 39 | *20* | 2 |
| Shields | 41 | 30 | 36 | 32 | 38 | 28 | 45 | 27 | 49 | 34 | 27 | 4 |
| Graham | 38·5 | 30·5 | 35·5 | 30·5 | 35·0 | 27·5 | 45·5 | 26·5 | 47·5 | 34·5 | 26·5 | 4 |
| Durham | 38·9 | 30·6 | 34·5 | 28·5 | 36·8 | 26·1 | 44·6 | 25·8 | 48·2 | 34·6 | 25·8 | 4 |
| Ushaw | 37·2 | 28·3 | 33·0 | 26·7 | 35·0 | 25·0 | 43·5 | 24·2 | 47·9 | 32·0 | 24·2 | 4 |
| Rounton | 38·8 | 28·6 | 35·2 | 23·7 | 36·9 | 22·5 | 42·3 | 25·7 | 47·1 | 34·6 | 22·5 | 3 |
| Scarborough | 36·8 | 28·5 | 33·7 | 30·0 | 36·4 | 24·8 | 38·5 | 24·3 | 45·0 | 36·3 | 24·3 | 4 |
| Driffield | 37·2 | 24·5 | 32·5 | 28·5 | 39·8 | 18·6 | 40·5 | 14·5 | 48·3 | 35·2 | *14·5* | 4 |
| York | 40 | 28 | 36 | 28 | 37 | 25 | 44 | 25 | 49 | 29 | 25 | 3<br>4 |
| Spurn Head | 38 | 30 | 32 | 28 | 35 | 28 | 40 | 28 | 45 | 30 | 28 | 2 |
| Appleby | 38·3 | 26·8 | 33·5 | 27·3 | 34·8 | 25·5 | 37·5 | 21·8 | 47·6 | 32·0 | 21·8 | 4 |
| Lincoln | 38·0 | 26·6 | 31·8 | 27·2 | 34·8 | 23·5 | 40·4 | 19·8 | 47·6 | 26·7 | *19·8* | 4 |
| 2. England N.W. | | | | | | | | | | | | |
| Scaleby | 39·7 | 28·9 | 37·2 | 26·4 | 40·7 | 21·4 | 43·7 | 23·4 | 47·2 | 35·1 | 21·4 | 3 |
| Newton Reigny | 37·8 | 31·2 | 34·9 | 23·5 | 39·0 | 19·0 | 44·0 | 30·1 | 45·9 | 34·9 | *19·0* | 3 |
| Seathwaite | 36·6 | 30·3 | 36·1 | 25·2 | 39·6 | 23·4 | 44·4 | 24·9 | 45·7 | 36·3 | 23·4 | 3 |
| Hawes Junction | 32 | 23 | 28 | 18 | 35 | 16 | 39 | 19 | 44 | 28 | 16 | 3 |
| Aysgarth | 34·8 | 27·5 | 31·1 | 22·5 | 33·9 | 17·5 | 42·0 | 21·5 | 47·7 | 33·8 | 17·5 | 3 |
| Kirkham | 42 | 22 | 37 | 19 | 42 | 24 | 46 | 34 | 47 | 42 | 19 | 2 |
| Stonyhurst | 38·6 | 29·1 | 34·5 | 24·8 | 35·7 | 22·7 | 43·3 | 24·2 | 44·5 | 35·4 | 22·7 | 3 |
| Blackpool | 41·0 | 32·0 | 35·0 | 25·2 | 37·2 | 24·0 | 44·0 | 29·5 | 45·8 | 29·5 | *24·0* | 3 |
| Bolton | 38·5 | 28·1 | 33·0 | 26·3 | 32·9 | 24·6 | 41·9 | 22·7 | 45·2 | 28·4 | 22·7 | 4 |
| Manchester | 38·1 | 27·6 | 33·3 | 25·4 | 33·7 | 24·7 | 42·1 | 23·2 | 46·2 | 36·2 | 23·2 | 4 |
| Liverpool | 40 | 32 | 34 | 27 | 34 | 26 | 44 | 28 | 45 | 32 | 26 | 3 |
| Macclesfield | 36·1 | 21·7 | 31·3 | 23·7 | 33·4 | 21·0 | 41·1 | 22·1 | 44·9 | 26·6 | 21·0 | 3 |
| Northwich | 40 | 29 | 39 | 25 | 37 | 25 | 42 | 22 | 46 | 29 | 22 | 4 |
| Llandudno | 40·0 | 34·0 | 36·2 | 30·0 | 35·0 | 26·8 | 44·0 | 25·4 | 46·9 | 39·8 | *25·4* | 4 |
| Holyhead | 41 | 36 | 37 | 32 | 38 | 31 | 46 | 30 | 48 | 37 | *30·0* | 4 |
| 3. Midland Counties. | | | | | | | | | | | | |
| Harrogate | 37·4 | 29·8 | 31·4 | 25·8 | 33·9 | 24·3 | 42·4 | 24·8 | 46·9 | 33·3 | 24·3 | 3 |
| Wakefield | 38·7 | 32·0 | 33·9 | 27·3 | 35·4 | 24·8 | 40·7 | 23·2 | 47·8 | 35·0 | 23·2 | 4 |
| Bawtry | 39 | 29 | 39 | 25 | 34 | 22 | 38 | 21 | 43 | 28 | *21* | 4 |
| Hodsock | 38·7 | 28·2 | 34·0 | 25·2 | 36·9 | 22·5 | 42·8 | 19·7 | 49·6 | 29·4 | 19·7 | 4 |
| Sheffield | 37·5 | 29·3 | 34·4 | 26·2 | 34·3 | 24·4 | 40·4 | 23·1 | 45·7 | 31·3 | 23·1 | 4 |
| Buxton | 32·4 | 25·6 | 29·9 | 21·2 | 33·1 | 13·5 | 36·9 | 10·9 | 45·2 | 19·5 | *10·9* | 4 |
| Southwell | 39·9 | 27·5 | 33·7 | 25·5 | 36·5 | 22·3 | 42·3 | 17·2 | 49·2 | 27·4 | *17·2* | 4 |
| Belper | 37·1 | 26·9 | 31·4 | 25·8 | 34·1 | 23·1 | 41·4 | 19·1 | 46·8 | 26·6 | *19·1* | 4 |
| Strelley | 38·2 | 25·1 | 33·1 | 22·0 | 35·0 | 20·0 | 40·1 | 18·2 | 48·9 | 26·1 | *18·2* | 4 |
| Cheadle | 35·6 | 26·0 | 33·0 | 24·5 | 34·0 | 22·0 | 38·7 | 21·4 | 44·5 | 34·6 | 21·4 | 4 |
| Loughborough | 39 | 28 | 35 | 26 | 39 | 23 | 42 | 18 | 48 | 21 | *18* | 4 |
| Stamford | 39 | 26 | 32 | 23 | 34 | 22 | 40 | 12 | 48 | 25 | *12* | 4 |
| Sutton Coldfield | 37·5 | 27·4 | 34·2 | 26·0 | 36·1 | 21·8 | 37·1 | 16·6 | 45·2 | 30·0 | *16·6* | 4 |
| Churchstoke | 39·0 | 23·0 | 33·8 | 21·5 | 33·8 | 22·1 | 42·1 | 16·5 | 46·1 | 38·0 | *16·5* | 4 |
| Stokesay | 40·7 | 27·6 | 34·3 | 25·6 | 34·8 | 24·1 | 40·6 | 16·6 | 45·9 | 37·1 | *16·6* | 4 |
| Uppingham | 34·2 | 25·2 | 32·7 | 22·7 | 34·7 | 21·0 | 34·0 | 19·9 | 43·6 | 32·8 | *19·9* | 4 |
| Rugby | 38 | 25·4 | 33 | 23·6 | 34·6 | 21·6 | 35 | 17 | 46·2 | 33 | 17 | 4 |
| Kenilworth | 38·8 | 26·5 | 32·7 | 24·3 | 33·3 | 22·0 | 41·8 | 16·1 | 47·7 | 25·4 | 16·1 | 4 |
| Aspley Guise | 37·4 | 25·3 | 37·3 | 22·9 | 32·0 | 18·0 | 39·8 | 16·2 | 47·1 | 30·4 | *16·2* | 4 |
| Burghill | 44·6 | 26·9 | 34·4 | 26·8 | 35·6 | 23·5 | 44·4 | 15·2 | 48·5 | 26·5 | 15·2 | 4 |
| Hereford | 44·6 | 26·9 | 34·4 | 26·8 | 35·6 | 23·5 | 44·4 | 15·2 | 48·5 | 28·5 | *15·2* | 4 |
| Ross | 45·6 | 27·4 | 34·8 | 26·9 | 37·5 | 23·3 | 44·0 | 15·8 | 50·8 | 26·1 | *15·8* | 4 |
| Gloucester | .. | 27·2 | .. | 24·9 | .. | 20·0 | .. | 14·9 | .. | 34·0 | 14·9 | 4 |
| Cheltenham | 38·6 | 22·5 | 34·3 | 25·2 | 34·6 | 22·6 | 39·2 | 15·2 | 46·6 | 37·3 | *15·2* | 4 |
| Oxford | 39 | 26 | 34 | 25 | 35 | 21 | 41 | 17 | 46 | 20 | *17* | 4 |
| Cirencester | 33 | 23 | 38 | 25 | 33 | 20 | 42 | 15 | 48 | 28 | *15* | 4 |
| Berkhamsted | 35·2 | 25·3 | 32·7 | 21·2 | 31·2 | 18·8 | 33·6 | 13·8 | 45·4 | 32·0 | *13·8* | 4 |

TABLE I.

SHADE TEMPERATURES OBSERVED FROM MARCH 1st to 5th, 1890.—*Continued.*

The Minimum Temperatures printed in italics are the lowest recorded during the Winter of 1889–90.

| Stations. | 1. Max. | 1. Min. | 2. Max. | 2. Min. | 3. Max. | 3. Min. | 4. Max. | 4. Min. | 5. Max. | 5. Min. | Min. | Date. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **4. England, E.** | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Hillington | 34·3 | 24·6 | 32·3 | 24·2 | 35·3 | 11·0 | 35·2 | 6·0 | 44·2 | 31·1 | *6·0* | 4 |
| Yarmouth | 34 | 23 | 33 | 26 | 33 | 25 | 36 | 22 | 44 | 25 | *22* | 4 |
| Somerleyton | 34·4 | 20·1 | 30·8 | 23·8 | 35·0 | 23·3 | 38·7 | 15·1 | 47·0 | 29·1 | *15·1* | 4 |
| Geldeston | 33·6 | 23·2 | 33·9 | 23·2 | 36·1 | 23·1 | 33·9 | 15·0 | 43·3 | 29·0 | *15·0* | 4 |
| Lowestoft | 35·0 | 23·8 | 36·0 | 24·2 | 37·0 | 25·2 | 34·2 | 20·9 | 41·5 | 29·2 | *20·9* | 4 |
| Wryde | .. | 24·8 | .. | 24·0 | .. | 18·8 | .. | 15·3 | .. | 23·8 | 15·3 | 4 |
| Cambridge | 35 | 24 | 31 | 19 | 35 | 15 | 40 | 14 | 47 | 19 | *14* | 4 |
| Sudbury | 33 | 26 | 32 | 23 | 34 | 18 | 36 | 14 | 43 | 31 | *14* | 4 |
| Royston | 35·4 | 23·5 | 32·6 | 18·8 | 37·9 | 16·5 | 41·3 | 15·3 | 46·9 | 34·0 | *15·3* | 4 |
| Hitchin | 39·0 | 25·2 | 35·1 | 18·4 | 29·3 | 14·5 | 31·0 | 13·0 | 39·4 | 30·4 | 13·0 | 4 |
| Rothamsted | 35·4 | 26·0 | 32·2 | 21·0 | 30·6 | 18·2 | 35·0 | 11·2 | 43·0 | 30·0 | *11·2* | 4 |
| Chelmsford | 34·0 | 23·4 | 30·9 | 20·0 | 33·0 | 17·9 | 38·9 | 6·8 | 45·8 | 25·1 | 6·8 | 4 |
| Ingatestone | 33·7 | 24·9 | 30·8 | 20·9 | 32·2 | 17·8 | 38·4 | 13·5 | 45·1 | 27·5 | *13·5* | 4 |
| **5. England, S.** | | | | | | | | | | | | |
| London (Old Street, E.C.) | 35·1 | 27·7 | 31·9 | 24·6 | 34·2 | 21·5 | 41·2 | 20·9 | 48·2 | 25·5 | *20·9* | 4 |
| Brixton | 36 | 25 | 32 | 26 | 33 | 23 | 41 | 15 | 46 | 18 | *15* | 4 |
| Kensington | 39 | 24 | 35 | 25 | 32 | 21 | 31 | 16 | 39 | 17 | *16* | 4 |
| Notting Hill | 34·4 | 25·6 | 32·2 | 22·3 | 32·4 | 20·9 | 34·1 | 18·3 | 44·3 | 34·1 | *18·3* | 4 |
| Camden Square | 35·0 | 25·8 | 33·4 | 23·2 | 34·5 | 19·8 | 40·8 | 15·6 | 48·4 | 25·2 | *15·6* | 4 |
| Regent's Park | 33·5 | 24·4 | 29·8 | 23·4 | 31 | 20·4 | 40·5 | 16·5 | 48·0 | 31·5 | *16·5* | 4 |
| Kew | 35·1 | 27·6 | 33·1 | 23·8 | 31·9 | 22·4 | 34·5 | 18·3 | 44·3 | 34·1 | *18·3* | 4 |
| West Norwood | 35·9 | 24·1 | 33·7 | 24·7 | 31·8 | 22·2 | 33·7 | 14·8 | 44·5 | 29·9 | *14·8* | 4 |
| Croydon, Whitgift | 36·1 | 25·2 | 34·8 | 24 | 31 | 20·5 | 33 | 10 | 41 | 28 | *10* | 4 |
| Addiscombe | 36·2 | 24·9 | 29·8 | 23·3 | 31·1 | 20·1 | 40·0 | 8·5 | 47·3 | 23·2 | *8·5* | 4 |
| Addington Hills | 26·9 | 22·8 | 28·7 | 21·0 | 38·0 | 17·5 | 45·7 | 14·5 | 51·0 | 23·5 | 14·5 | 4 |
| Waddon | 36·4 | 24·0 | 30·0 | 24·0 | 30·6 | 20·0 | 39·4 | 17·0 | 47 6 | 28·0 | 17·0 | 4 |
| Beddington | 36·1 | 23·9 | 30·0 | 24·7 | 31·0 | 21·0 | 40·1 | 5·4 | 47·7 | 21·3 | *5·4* | 4 |
| Kenley | 36·5 | 25 | 22 | 24 | 22 | 20 | 39 | 6 | 46 | 29 | *6* | 4 |
| Wallington | 36·1 | 24·3 | 33·7 | 23·1 | 32·2 | 20·1 | 36·2 | 9·8 | 44·0 | 30·1 | *9·8* | 4 |
| Egham | 35·1 | 26·1 | 29·5 | 23·9 | 30·7 | 20·8 | 40·1 | 19·1 | 48·1 | 25·1 | 19·1 | 4 |
| Reigate | 35 | 25 | 33 | 23 | 34 | 19 | 41 | 9 | 44 | 26 | 9 | 4 |
| Brockham | 37·3 | 20·1 | 30·4 | 20·5 | 30·2 | 19·8 | 34·9 | 9·0 | 47·3 | 28·4 | 9·0 | 4 |
| Dorking | 35 | 25 | 31 | 22 | 31 | 18 | 40 | 14 | 46 | 25 | *14* | 4 |
| Epsom | 35·7 | 25·0 | 29·2 | 23·3 | 29·8 | 19·0 | 32·5 | 15·3 | 45·0 | 30·5 | *15·3* | 4 |
| Beckenham | 37·7 | 23·7 | 35·0 | 22·5 | 34·2 | 18·5 | 40·5 | 7·3 | 47·3 | 17·3 | *7·3* | 4 |
| Greenwich | 37·3 | 25·3 | 32·6 | 22·1 | 33·3 | 20·1 | 35·0 | 13·1 | 44·0 | 32·4 | *13·1* | 4 |
| Eltham | 35 | 22 | 30 | 21 | 30 | 18 | 38 | 10 | 43 | 23 | *10* | 4 |
| Chatham | 37 | 25 | 31 | 20 | 32 | 15 | 40 | 24 | 48 | 38 | 15 | 3 |
| Maidstone | 31 | 26·5 | 32 | 20·5 | 40·5 | 10 | 46 | 19 | 52 | 35 | *10* | 3 |
| Marlborough | 36·4 | 22·7 | 32·3 | 24·8 | 32·8 | 19·6 | 41·6 | 12·9 | 46·1 | 24·9 | *12·9* | 4 |
| Reading | 34·6 | 23·0 | 30·5 | 23·5 | 31·2 | 20·0 | 38·0 | 14·8 | 43·6 | 29·0 | 14·8 | 4 |
| Strathfield Turgiss | 36·9 | 25·9 | 33·2 | 25·5 | 33·0 | 21·2 | 42·8 | 13·8 | 47·3 | 24·3 | *13·8* | 4 |
| Stowell | 35·8 | 25·2 | 33·1 | 26·7 | 31·0 | 20·2 | 41·7 | 19·1 | 45·4 | 27·0 | *19·1* | 4 |
| Harestock | 37·4 | 23·0 | 34·3 | 23·8 | 32·3 | 19·8 | 36·2 | 16·6 | 44·3 | 30·4 | *16·6* | 4 |
| Swarraton | 34·6 | 24·0 | 30·0 | 25·2 | 31·4 | 19·5 | 40·5 | 12·0 | 45·0 | 22·0 | 12·0 | 4 |
| Cranbrook | 36 | 23 | 31 | 24 | 33 | 18 | 37 | 10 | 44 | 16 | *10* | 4 |
| Crowborough | 35·0 | 22·8 | 28·0 | 23·4 | 29·8 | 15·8 | 31·4 | 16·2 | 42·2 | 27·6 | *15·8* | 3 |
| Tenterden | 36 | 24 | 32 | 28 | 34 | 20 | 34 | 14 | 42 | 25 | *14* | 4 |
| Parkstone | 37·7 | 25·4 | 36·0 | 24·8 | 33·4 | 20·4 | 36·7 | 18·0 | 47·3 | 34·0 | *18·0* | 4 |
| Margate | 35 | 26·2 | 34·0 | 25 | 31·7 | 24 | 33·5 | 15·2 | 42·8 | 26 | *15·2* | 4 |
| Ramsgate | 34·2 | 25·2 | 32·0 | 28·4 | 32·9 | 23·3 | 38·1 | 16·4 | 44·6 | 24·0 | *16·4* | 4 |
| Dungeness | 38 | 22 | 33 | 25 | 32 | 21 | 37 | 13 | 44 | 14 | *13* | 4 |
| Hastings | 39·1 | 24·5 | 32·8 | 28·2 | 31·3 | 21·7 | 40·8 | 17·4 | 47·0 | 26·2 | *17·4* | 4 |
| Eastbourne | 40·0 | 28·6 | 43·6 | 25·0 | 33·0 | 22·6 | 35·0 | 20·0 | 47·0 | 33·0 | *20·0* | 4 |

## TABLE I.

SHADE TEMPERATURES OBSERVED FROM MARCH 1ST TO 5TH, 1890.—*Continued.*

**The Minimum Temperatures printed in italics are the lowest recorded during the Winter of 1889–90.**

| Stations. | 1. | | 2. | | 3. | | 4. | | 5. | | Min. | Date. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. | | |
| 5. England, S.—*Continued.* | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | |
| Brighton | 36·9 | 27·0 | 31·8 | 21·1 | 31·0 | 20·0 | 37·8 | 24·0 | 43·1 | 34·0 | *20·0* | 3 |
| Worthing | 38·7 | 24·0 | 32·4 | 26·3 | 32·9 | 21·4 | 42·4 | 19·4 | 44·9 | 26·5 | *19·4* | 4 |
| Portsmouth | 36 | 28 | 35 | 29 | 34 | 22 | 42 | 19 | 47 | 29 | 19 | 4 |
| Gosport | 44·0 | 25 | 34·2 | 27·5 | 32·6 | 22·6 | 41·6 | 21·6 | 43·6 | 25·8 | 21·6 | 4 |
| Southampton | 39·6 | 25·3 | 35·7 | 25·5 | 34·9 | 22·0 | 37·1 | 19·5 | 47·4 | 32·2 | *19·5* | 4 |
| Totland Bay, I.W. | 40 | 30 | 33 | 29 | 33 | 24 | 41 | 23 | 45 | 28 | *23* | 4 |
| Ventnor, I.W. | 40·8 | 28·6 | 33·3 | 28·6 | 32·4 | 22·7 | 42·0 | 23·7 | 48·5 | 27·9 | 22·7 | 3 |
| Hurst Castle | 40 | 28 | 37 | 29 | 37 | 24 | 42 | 23 | 47 | 25 | *23* | 4 |
| Southbourne | 38·9 | 27·4 | 34·4 | 28·4 | 33·0 | 26·5 | 44·0 | 18·4 | 47·7 | 27·4 | *18·4* | 4 |
| Weymouth | 39·5 | 29·0 | 34·5 | 30·0 | 33·0 | 23·0 | 42·5 | 22·7 | 48·0 | 29·0 | 22·7 | 4 |
| Rousdon | 39·0 | 26·4 | 36·5 | 23·4 | 30·9 | 19·6 | 34·0 | 18·2 | 46·8 | 33·5 | *18·2* | 4 |
| 6. England, S.W. | | | | | | | | | | | | |
| Gwernyfed Park | 40·2 | 27·4 | 35·4 | 27·3 | 33·8 | 21·7 | 42·6 | 15·8 | 46·9 | 21·4 | 15·8 | 4 |
| Llandovery | 43 | 27 | 36 | 27 | 37 | 19 | 45 | 14 | 49 | 21 | *14* | 4 |
| St. David's | 42·7 | 34·6 | 37·9 | 27·8 | 36·1 | 24·2 | 45·0 | 26·1 | 48·4 | 41·1 | *24·2* | 3 |
| Carmarthen | 44·5 | 31·8 | 37·5 | 25·5 | 37·5 | 23·2 | 42·3 | 15·0 | 49·1 | 34·8 | 15·0 | 4 |
| Pembroke | 42 | 33 | 37 | 30 | 35 | 27 | 46 | 28 | 47 | 32 | *27* | 4 |
| Weston-super-Mare | 43·0 | 33·1 | 37·8 | 29·0 | 35·7 | 25·2 | 44·2 | 21·2 | 47·8 | 29·8 | *21·2* | 4 |
| Ilfracombe | 42·5 | 35 | 35·6 | 32 | 34·8 | 29 | 46 | 28·6 | 49·5 | 33 | *28·6* | 4 |
| Arlington | 40 | 28 | 33 | 28 | 32 | 23 | 43 | 19 | 45 | 25 | *19* | 4 |
| South Molton | 40·5 | 26·5 | 34·5 | 28·5 | 32·0 | 25·0 | 44·0 | 15·5 | 45·7 | 23·0 | 15·5 | 4 |
| Cullompton | 42·2 | 25·1 | 35·0 | 29·1 | 33·2 | 21·9 | 45·8 | 14·8 | 49·1 | 27·9 | *14·8* | 4 |
| Bude | 42·1 | 30·6 | 38·2 | 31·1 | 37·0 | 23·9 | 46·0 | 20·1 | 47·7 | 36·4 | 20·1 | 4 |
| Brampford Speke | 41·7 | 25·9 | 37·6 | 29·3 | 33·8 | 22·5 | 43·6 | 17·2 | 48·0 | 26·4 | 17·2 | 4 |
| Exeter | 42·0 | 30·8 | 36·6 | 30·0 | 33·6 | 23·5 | 44·0 | 20·5 | 48·5 | 25·8 | 20·5 | 4 |
| Ashburton | 42·7 | 30·3 | 37·7 | 28·9 | 34·6 | 22·9 | 42·7 | 22·6 | 49·3 | 30·0 | *22·6* | 4 |
| Sidmouth | 41·0 | 26·8 | 35·0 | 29·0 | 34·6 | 22·8 | 44·2 | 20·5 | 47·5 | 30·3 | 20·5 | 4 |
| Babbacombe | 43·4 | 28·8 | 37·1 | 28·1 | 32·3 | 24·7 | 38·5 | 24·5 | 49·6 | 35·8 | *24·5* | 4 |
| Torquay | 43 | 28 | 37 | 32 | 34 | 26 | 44 | 21 | 50 | 34 | 21 | 4 |
| Prawle Point | 43 | 29 | 37 | 30 | 34 | 26 | 43 | 23 | 49 | 27 | *23* | 4 |
| Plymouth | 42·7 | 31·5 | 37·4 | 31·1 | 34·5 | 23·5 | 44·3 | 23·0 | 48·2 | 27·5 | *23·0* | 4 |
| Falmouth | 42·5 | 33·2 | 37·7 | 30·3 | 32·8 | 25·7 | 39·7 | 24·1 | 46·5 | 38·8 | *24·1* | 4 |
| Channel Islands. | | | | | | | | | | | | |
| Scilly | 44 | 37 | 39 | 36 | 36 | 30 | 46 | 31 | 55 | 34 | *30* | 3 |
| Guernsey | 42·5 | 31·7 | 35·9 | 35·5 | 32·9 | 27·2 | 44·1 | 27·5 | 49·4 | 29·5 | *27·2* | 3 |
| Jersey | 41 | 30 | 40 | 35 | 33 | 26 | 44 | 21 | 49 | 23 | *21* | 4 |

SHEFFIELD.—Min. 23°·1. Temperature was slightly lower on March 4th, 1889; and on March 5th, 1886.

BUXTON.—Min. 10°·9. 10°·2 was recorded on March 3rd, 1887, and 9°·4 on March 4th, 1889.

SOUTHWELL.—Min. 17°·2. 15°·8 recorded on March 4th, 1889.

STRELLEY.—Min. 18°·2. Twice lower in March since 1880; 18°·8 March 7th, 1886, 15°·2 March 10th, 1883. Also one other winter temperature lower in 10 years, 0°·8, January 15th, 1881.

BELPER.—Min. 19°· There have been three Marches with lower temperatures during the last 13 years, viz. 1889, 1886, and 1883.

UPPINGHAM.—Min. 19°·9. Lower temperatures were experienced in March 1883 and 1889, and often in recent winters: the absolutely lowest since 1876 is 9°·5 on January 16th, 1881.

RUGBY.—Min. 17°· The thermometer registered 16°·6 on January 6th. A lower reading was observed in March 1886, the thermometer registering 15°·6; and in several recent winters lower temperatures have been recorded.

ASPLEY GUISE.—Min. 16°·2. The lowest reading in March since observations were commenced in 1871, but lower in several recent winters. Lowest temperature recorded 6°·9 on January 22nd, 1881.

ROSS.—Min. 15°·8. The only instance of a lower temperature in March was 15°·0 March 1st, 1866. Lower in 11 winters during the last 25 years, lowest 1°·8 December 31st, 1870.

CHELTENHAM.—Min. 15°·2. During the last 12 years lower temperatures have occurred twice in March, 12°·2 March 25th, 1878; 11°·2 March 16th, 1877. The temperature has fallen lower each winter except 1881-2, 1882-3, 1883-4, and 1884-5. The lowest temperature was —3°·3 January 20th, 1881.

BERKHAMSTED.—Min. 18°·8. No March with so low a temperature since observations were commenced in 1886, but each winter has had a lower reading with the exception of 1887-8.

ENGLAND, E.

SOMERLEYTON.—Min. 15°·1. No instance of so low a temperature in March since 1870, but a lower reading observed in 10 winters out of the 20.

ROYSTON.—Min. 15°·8. No reading so low in March during the last 39 years, but lower winter temperatures were observed in 18 years, the lowest was 1°·1 December 25th, 1860.

ENGLAND, S.

LONDON.—St. Luke's, Old Street.—Min. 20°·9. No record so low since observations commenced in 1883.

LONDON.—Holland House, Kensington.—Min. 16°. The shade temperature fell to 15° on December 31st, 1886.

LONDON.—Lansdowne Crescent, Notting Hill.—Min. 18°·3. Observations date from January 12th, 1879. No previous record so low in March. Lower readings in past winters, 11°·2 January 15th, 1881, 15°·2 January 2nd, 1887, 15°·4 December 7th, 1879, 17°·8 February 13th, 1889, 18°·2 January 7th, 1886. The range of temperature during March was 48°·7, which is the greatest range in any month during the last 12 years, excepting 50° in July 1881.

LONDON.—Camden Square.—Min. 15°·6. Observations commenced in 1859. No other record so low in March. Lower readings in past winters, 6°·7 December 1860 and January 1867, 11°·8 January 1881, 14°·0 December 1870, 14°·3 January 1861, 14°·4 December 1859, 14°·5 January 1887, 15°·1 January 1864, 15°·4 February 1865.

LONDON.—Royal Botanic Society's Gardens.—Min. 16°·5. Observations commenced in 1870. No previous record so low in March. Lower readings in past winters, 9°·8 in 1880-1, 12°·5 in 1879-80, 14° in 1873-4 and 1878-9, 15°·5 in 1875-6.

CROYDON.—Whitgift Grammar School.—Min. 10°. No record so low during the last six years.

ADDISCOMBE.—Min. 8°·5. No record so low since observations were commenced in 1873, 17 years. The young foliage on the roses was entirely destroyed.

WADDON.—Min. 17°. Once lower in March since 1882, reading 11°·6 March 7th, 1886. Lower readings in previous winters 8° January 8th, 1886, 10° January 2nd, 1887, 11° December 22nd, 1886, 11°·6 January 7th, 1887, 12°·4 January 7th, 1886.

BEDDINGTON.—Min. 5°·4. No record so low during the last 10 years.

KENLEY.—Min. 6°. No record so low, but observations for two years only.

WALLINGTON.—Min. 9°·8. No record so low since observations were commenced in 1884.

EGHAM.—Cooper's Hill.—Min. 19°·1. The thermometer fell to 19° on December 29th, 1889, and lower readings have been recorded in eight previous winters since 1874; the minimum during the period was 8°·5 on January 15th, 1881.

CANTERBURY.—Miss Metcalfe, referring to the early morning of 4th, writes

TABLE II.

HOURLY RECORDS OF TEMPERATURE AT GREENWICH, KEW AND FALMOUTH.

| Hour. | March 3rd. | | | | | | March 4th. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greenwich. | | Kew. | | Falmouth. | | Greenwich. | | Kew. | | Falmouth. | |
| | Air. | Wet Bulb, Difference below. | Air. | Wet Bulb, Difference below. | Air. | Wet Bulb, Difference below. | Air. | Wet Bulb, Difference below. | Air. | Wet Bulb, Difference below. | Air. | Wet Bulb, Difference below. |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| 1 a.m. | 22·1 | .. | 23·2 | .. | 27·7 | 3·7 | 22·8 | .. | 24·5 | 2·2 | 26·9 | 3·9 |
| 2 ,, | 22·4 | .. | 22·4 | .. | 27·2 | 3·2 | 22·0 | .. | 23·1 | 1·6 | 27·2 | 3·2 |
| 3 ,, | 22·8 | .. | 22·9 | .. | 26·9 | 2·8 | 19·8 | .. | 22·2 | 1·5 | 26·6 | 2·7 |
| 4 ,, | 23·1 | .. | 23·4 | .. | 26·8 | 2·6 | 18·9 | .. | 20·3 | 0·9 | 25·5 | 2·2 |
| 5 ,, | 22·7 | .. | 23·7 | .. | 26·8 | 2·4 | 18·4 | .. | 19·8 | 0·9 | 25·1 | 1·9 |
| 6 ,, | 22·4 | .. | 23·6 | .. | 26·0 | 2·0 | 15·2 | .. | 19·1 | 0·4 | 24·0 | 1·8 |
| 7 ,, | 21·6 | .. | 23·2 | .. | 25·3 | 2·1 | 14·1 | .. | 18·4 | 0·4 | 24·1 | 2·0 |
| 8 ,, | 22·9 | .. | 23·5 | .. | 25·9 | 2·3 | 15·3 | .. | 20·0 | 1·0 | 24·6 | 1·8 |
| 9 ,, | 25·0 | 2·2 | 24·2 | .. | 27·6 | 2·6 | 19·2 | 0·9 | 24·2 | 1·4 | 27·0 | 2·0 |
| 10 ,, | 27·6 | .. | 26·5 | .. | 29·6 | 2·6 | 24·0 | .. | 27·0 | 2·4 | 30·1 | .. |
| 11 ,, | 30·4 | .. | 28·9 | .. | 30·7 | 2·9 | 27·8 | .. | 29·4 | 3·8 | 32·9 | 3·7 |
| Noon | 31·9 | 3·9 | 30·2 | .. | 31·0 | 4·0 | 31·8 | 3·8 | 31·0 | 4·3 | 33·9 | 4·0 |
| 1 p.m. | 31·8 | .. | 30·7 | 4·8 | 31·4 | 4·6 | 32·7 | .. | 33·2 | 5·1 | 35·1 | 4·2 |
| 2 ,, | 31·5 | .. | 31·0 | 4·8 | 31·8 | 4·5 | 32·6 | .. | 33·7 | 5·0 | 36·3 | 4·7 |
| 3 ,, | 31·3 | 4·5 | 31·0 | 5·0 | 31·8 | 4·8 | 32·5 | 4·0 | 34·3 | 5·3 | 36·2 | 4·3 |
| 4 ,, | 30·3 | .. | 30·7 | 5·0 | 31·6 | 4·5 | 32·9 | .. | 33·2 | 5·1 | 36·8 | 4·8 |
| 5 ,, | 29·0 | .. | 29·9 | 4·4 | 31·7 | 4·7 | 31·5 | .. | 32·9 | 4·6 | 35·3 | 3·1 |
| 6 ,, | 28·1 | .. | 29·2 | 3·1 | 30·8 | 4·2 | 30·1 | .. | 32·0 | 4·0 | 34·7 | 3·0 |
| 7 ,, | 26·8 | .. | 28·0 | 2·6 | 29·7 | .. | 29·2 | .. | 31·0 | 3·2 | 35·0 | 3·0 |
| 8 ,, | 26·5 | .. | 26·3 | 1·7 | 29·2 | 4·3 | 29·2 | .. | 31·0 | 3·2 | 36·5 | 2·6 |
| 9 ,, | 25·4 | 1·3 | 25·7 | 1·8 | 27·3 | 3·1 | 30·4 | 2·9 | 31·7 | 3·6 | 38·1 | 2·5 |
| 10 ,, | 25·1 | .. | 25·0 | 2·0 | 26·0 | 2·6 | 31·4 | .. | 31·9 | 3·1 | 39·1 | 2·1 |
| 11 ,, | 25·2 | .. | 25·0 | 2·2 | 26·1 | 3·3 | 31·4 | .. | 32·7 | 1·7 | 40·0 | 1·5 |
| Midnt. | 24·7 | .. | 25·3 | 2·2 | 25·1 | 2·9 | 32·6 | .. | 34·0 | 2·1 | 40·1 | 0·5 |

that a large rose grower in Canterbury had by this severe night lost nearly £300 worth of roses.

BROCKHAM.—Min. 9°. All unprotected tea roses killed to the ground; also many hybrid perpetual roses.

DORKING.—Min. 14°. Temperature has fallen lower only in four winters since observations were commenced in 1870, these were 11° December 23rd, 1870, 13° January 8th, 1876, 12° January 15th, 1881, 12° January 17th, 1887.

BECKENHAM.—Min. 7°·3. Mr. Bicknell notes there has been skating in March in four consecutive years, a very rare, probably unprecedented, occurrence.

1887. March 21st. Skating in St. James's Park.
1888. Several days up to and including March 5th. }
1889. March 6th. } At the Skating Club, Regent's Park.
1890. March 4th and 5th. }

ELTHAM.—Min. 10°. The lowest reading during eight years that observations have been made; the next lowest was 13° on January 17th, 1887.

MARLBOROUGH.—Min. 12°·9. In March 1887 the shade thermometer fell to 4°·5, and lower readings than in March this year were recorded in eight winters since 1865.

HARESTOCK.—Min. 16°·6. No March reading so low since observations were commenced in 1880, but lower readings in two winters, viz. 10°·1 on January 17th, 1881, and 14°·5 on January 1st, 1887.

CRANBROOK.—Min. 10°. With the exception of 4° on January 22nd and 8° on

## TABLE III.

Hourly Records of Barometer at Greenwich, Kew and Falmouth.

| Hours. | March 3rd. | | | | | | March 4th. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greenwich. | | Kew. | | Falmouth. | | Greenwich. | | Kew. | | Falmouth. | |
| | Barometer. | Hourly Change. | Barometer. | Hourly Change. | Barometer. | Hourly Change. | Barometer. | Hourly Change. | Barometer. | Hourly Change. | Barometer. | Hourly Change. |
| | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| 1 a.m. | 30·175 | .. | 30·343 | .. | 30·177 | .. | 30·296 | —·004 | 30·457 | ·000 | 30·306 | —·013 |
| 2 ,, | ·184 | +·009 | ·355 | +·012 | ·175 | —·002 | ·283 | —·013 | ·440 | —·017 | ·300 | —·006 |
| 3 ,, | ·175 | —·009 | ·349 | —·006 | ·176 | +·001 | ·274 | —·009 | ·437 | —·003 | ·281 | —·019 |
| 4 ,, | ·180 | +·005 | ·346 | —·003 | ·181 | +·025 | ·255 | —·019 | ·424 | —·013 | ·263 | —·018 |
| 5 ,, | ·180 | ·000 | ·353 | +·007 | ·185 | +·004 | ·257 | +·002 | ·423 | —·001 | ·252 | —·011 |
| 6 ,, | ·196 | +·016 | ·366 | +·013 | ·201 | +·016 | ·250 | —·007 | ·416 | —·007 | ·254 | +·002 |
| 7 ,, | ·232 | +·036 | ·397 | +·031 | ·225 | +·024 | ·253 | +·003 | ·416 | ·000 | ·257 | +·003 |
| 8 ,, | ·267 | +·035 | ·431 | +·034 | ·247 | +·022 | ·264 | +·011 | ·424 | +·008 | ·256 | —·001 |
| 9 ,, | ·294 | +·027 | ·460 | +·029 | ·257 | +·010 | ·254 | —·010 | ·419 | —·005 | ·253 | —·003 |
| 10 ,, | ·305 | +·011 | ·469 | +·009 | ·259 | +·002 | ·236 | —·018 | ·403 | —·016 | ·247 | —·006 |
| 11 ,, | ·310 | +·005 | ·473 | +·004 | ·259 | ·000 | ·215 | —·021 | ·380 | —·023 | ·238 | —·009 |
| Noon | ·315 | +·005 | ·471 | —·002 | ·267 | +·008 | ·203 | —·012 | ·361 | —·019 | ·230 | —·008 |
| 1 p.m. | ·310 | —·005 | ·467 | —·004 | ·271 | +·004 | ·155 | —·048 | ·311 | —·050 | ·204 | —·026 |
| 2 ,, | ·305 | —·005 | ·460 | —·007 | ·263 | —·008 | ·117 | —·038 | ·267 | —·044 | ·173 | —·031 |
| 3 ,, | ·294 | —·011 | ·455 | —·005 | ·261 | —·002 | ·082 | —·035 | ·235 | —·032 | ·143 | —·030 |
| 4 ,, | ·284 | —·010 | ·441 | —·014 | ·261 | ·000 | ·052 | —·030 | ·212 | —·023 | ·131 | —·012 |
| 5 ,, | ·292 | +·008 | ·447 | +·006 | ·265 | +·004 | 30·030 | —·022 | ·182 | —·030 | ·101 | —·030 |
| 6 ,, | ·295 | +·003 | ·452 | +·005 | ·281 | +·016 | 29·996 | —·034 | ·149 | —·033 | ·091 | —·010 |
| 7 ,, | ·300 | +·005 | ·459 | +·007 | ·301 | +·020 | ·965 | —·031 | ·125 | —·024 | ·063 | —·062 |
| 8 ,, | ·302 | +·002 | ·460 | +·001 | ·319 | +·018 | ·926 | —·039 | ·079 | —·046 | ·040 | —·039 |
| 9 ,, | ·298 | —·004 | ·456 | —·004 | ·323 | +·004 | ·870 | —·056 | 30·031 | —·048 | 30·017 | —·014 |
| 10 ,, | ·305 | +·007 | ·464 | +·008 | ·325 | +·002 | ·823 | —·047 | 29·979 | —·052 | 29·973 | —·006 |
| 11 ,, | ·310 | +·005 | ·471 | +·007 | ·321 | —·004 | ·785 | —·038 | ·941 | —·038 | ·937 | —·004 |
| Midnt. | 30·300 | —·010 | 30·457 | —·014 | 30·319 | —·002 | 29·744 | —·041 | 29·897 | —·044 | 29·881 | —·016 |

January 23rd in 1881, no lower reading has been observed during the last 25 years. The next lowest reading in March was 19° on the 11th, in 1874.

Tenterden.—Min. 14°. Nothing lower since January 1881, when 10° was registered on the 22nd. Mr. Mace remarks: "Shrubs are not much cut up here, but on low ground at Pluckley, Bethersdon, Headcorn, and Romney Marsh, they are badly damaged, evidencing much lower temperatures." He has also heard of a Six's thermometer falling to 6° at Tenterden, but it was not properly screened. The time of greatest cold is thought by men who were out early to have been about 6 a.m., and as not having been nearly so keen at an earlier hour.

Parkstone.—Min. 18°. This is the lowest temperature registered since observations were commenced in April 1882, the next lowest was 18°·2 December 11th, 1882.

Eastbourne.—Min. 19°·5. Lower in three winters since records commenced in 1880. 14° in January 1880, 12°·8 in January 1881, 17°·9 in February 1888.

Brighton.—Min. 20°. No record of such cold in March, at any rate not for the last 45 years.

Worthing.—Min. 19°·4. Observations recorded since 1855. One instance of a lower March temperature, 18° in 1867. During the 85 years a lower winter temperature has occurred in 6 years.

Totland Bay, I. W.—Min. 23°. The lowest reading during the last four years.

Southbourne-on-Sea.—Min. 18°·4. The lowest record in March during the

## TABLE IV.

### Hourly Records of Wind at Greenwich, Kew and Falmouth.

| Hour. | March 3rd. | | | | | | March 4th. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Greenwich. | | Kew. | | Falmouth. | | Greenwich. | | Kew. | | Falmouth. | |
| | Direction. | Velocity. | Direction. | Velocity. | Direction. | Velocity. | Direction. | Velocity. | Direction. | Velocity. | Direction. | Velocity. |
| | | Miles. | | Miles. | | Miles. | | Miles. | | Miles. | | Miles. |
| 1 a.m. | NE | 16 | NNE | 13 | NE | 23 | NE | 6 | N | 8·5 | NEbN | 9·5 |
| 2 ,, | NE | 15 | NbE | 15 | NE | 23 | NE | 6 | N | 6·5 | NEbN | 7·5 |
| 3 ,, | NNE | 18 | NbE | 15 | NE | 20 | N | 1 | N | 5·5 | NEbN | 5·5 |
| 4 ,, | NNE | 13 | NbE | 16 | NEbN | 19 | E | 1 | N | 3 | NEbN | 6·5 |
| 5 ,, | NNE | 17 | NbE | 14 | NEbN | 18 | NNE | 1 | N | 2 | NE | 4·5 |
| 6 ,, | NE | 13 | NNE | 16 | NE | 22 | W | 1 | N | 2 | NE | 4·5 |
| 7 ,, | NE | 9 | NEbN | 15 | NE | 21 | W | 4 | N | 3 | NE | 4·5 |
| 8 ,, | NE | 8 | NEbN | 8·5 | NE | 21 | SW | 3 | N | 2 | NE | 4·5 |
| 9 ,, | NE | 6 | NEbN | 7·5 | NE | 23 | SW | 6 | N | 4 | NE | 6·5 |
| 10 ,, | NE | 10 | NEbN | 7·5 | NE | 26 | SW | 3 | N | 5·5 | NEbN | 4 |
| 11 ,, | NNE | 10 | NE | 17 | NE | 25 | WSW | 9 | NWbW | 5·5 | ENE | 7·5 |
| Noon | NNE | 19 | NEbN | 16 | NE | 24 | WSW | 10 | WSW | 8·5 | EbN | 6·5 |
| 1 p.m. | NNE | 18 | NEbN | 15 | NE | 24 | SW | 11 | SW | 10·5 | E | 4·5 |
| 2 ,, | NNE | 18 | NNE | 17 | NEbE | 22 | SW | 12 | SSW | 14 | SSE | 5·5 |
| 3 ,, | NNE | 15 | NbE | 18 | ENE | 18 | SW | 13 | SW | 14 | SbE | 6·5 |
| 4 ,, | NNE | 16 | NbE | 16 | NEbE | 18 | SW | 16 | SWbW | 14 | S | 5·5 |
| 5 ,, | NNE | 15 | NbE | 11 | NEbE | 15 | SW | 14 | SW | 13 | SSW | 8·5 |
| 6 ,, | NNE | 11 | NbE | 14 | NE | 16 | SW | 14 | SW | 13 | WSW | 12 |
| 7 ,, | N | 13 | NbE | 10·5 | NE | 13 | SW | 19 | SWbS | 15 | WSW | 12 |
| 8 ,, | N | 14 | NbE | 9·5 | NE | 13 | SW | 19 | SWbS | 18 | WbS | 17 |
| 9 ,, | N | 10 | N | 10·5 | NEbN | 7·5 | SW | 22 | SW | 17 | WSW | 19 |
| 10 ,, | N | 11 | N | 10·5 | NEbN | 7·5 | SW | 23 | SW | 16 | WbS | 24 |
| 11 ,, | N | 10 | N | 9·5 | NEbN | 6·5 | SW | 26 | SW | 16 | WbS | 25 |
| Midnt. | NNE | 9 | N | 9·5 | NEbN | 5·5 | SW | 25 | SWbW | 16 | WbS | 27 |

**last 24 years. Only five winters with so low a temperature—the lowest 10°·5 on January 14th, 1867.**

**Rousdon.—Min. 18°·2. The lowest reading since observations were commenced in 1888.**

England, S.W.

**St. David's.—Min. 24°·2. No record of so low a reading in any winter since observations were commenced in 1878, the next lowest was 24°·4 March 2nd, 1888.**

Weston-super-Mare.—Min. 21°·2. Lower than in any March since observations were commenced in 1883, but lower readings occurred in January 1887 and 1889.

Ilfracombe.—Min. 28°·6. The temperature fell to 28° March 11th, 1886.

Ashburton.—Min. 22°·6. No March reading so low since observations were commenced in 1881, but lower in two winters, 15°·3 January 22nd, 1881, and 20°·7 February 25th, 1888.

**Babbacombe.—Min. 24°·5. Lower in March in five years since 1876, and lower in nearly every winter; lowest 15°·8 January 20th, 1881. Vegetation very much burnt up. The dryness throughout the frost was very remarkable.**

**Guernsey.—Min. 27°·8. Observations from 1881 do not show so low a record in March.**

TABLE V.—GREENWICH TEMPERATURES, 1841–90.

| Year. | March. Shade Temp. Max. Day. | Max. | Min. Day. | Min. | Range. | Grass Temp. Min. | Shade Temp. Monthly Mean. Max. | Min. | Max. and Min. | Winter. Lowest Shade Temperature. Year. | Date. | Lowest Temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° | | ° | ° | ° | ° | ° | ° | | | ° |
| 1841 | 26 | 66·9 | 2 | 29·5 | 37·4 | 26·3 | 56·3 | 38·7 | 47·5 | 1840– 1 | Jan 9, '41 | 4·0 |
| 1842 | 28 | 60·5 | 24 | 29·9 | 30·6 | 23·2 | 52·0 | 39·1 | 45·6 | 1841– 2 | Nov. 17, '41 | 22·6 |
| 1843 | 18 | 63·7 | 5 | 26·5 | 37·2 | 11·4 | 50·5 | 37·0 | 43·8 | 1842– 3 | Feb. 15, '43 | 20·3 |
| 1844 | 29 | 60·2 | 6 | 24·1 | 36·1 | 12·0 | 48·9 | 35·8 | 42·4 | 1843– 4 | Jan. 3, '44 | 18·8 |
| 1845 | 27 | 59·4 | 14 | 13·1 | 46·3 | 7·5 | 42·7 | 30·6 | 36·7 | 1844– 5 | Feb. 12, '45 | 7·7 |
| 1846 | 31 | 58·0 | 21 | 26·5 | 31·5 | 18·3 | 51·6 | 38·1 | 44·9 | 1845– 6 | Mar. 21, '46 | 26·5 |
| 1847 | 17 | 64·2 | 11 | 16·9 | 47·3 | 3·5 | 50·1 | 34·2 | 42·2 | 1846– 7 | Feb. 12, '47 | 11·2 |
| 1848 | 31 | 71·5 | 4 | 28·0 | 43·5 | 18·0 | 51·1 | 37·3 | 44·2 | 1847– 8 | Jan. 28, '48 | 16·8 |
| 1849 | 17 | 60·7 | 25 | 27·7 | 33·0 | 21·0 | 50·1 | 36·4 | 43·3 | 1848– 9 | Jan. 3, '49 | 19·9 |
| 1850 | 31 | 58·0 | 26 | 20·0 | 38·0 | 12·8 | 48·6 | 32·1 | 40·4 | 1849–50 | Dec. 29, '49 | 18·8 |
| 1851 | 20 | 58·4 | 9 | 29·8 | 28·6 | 23·0 | 49·5 | 37·4 | 43·5 | 1850– 1 | Feb. 17, '51 | 23·7 |
| 1852 | 23 | 68·4 | 5 | 21·3 | 47·1 | 11·5 | 50·7 | 32·2 | 41·5 | 1851– 2 | Mar. 5, '52 | 21·3 |
| 1853 | 13 | 60·5 | 25 | 20·8 | 39·7 | 12·2 | 47·0 | 31·2 | 39·1 | 1852– 3 | Feb. 19, '53 | 20·5 |
| 1854 | 13 | 64·2 | 3 | 24·6 | 39·6 | 14·8 | 55·3 | 35·4 | 45·4 | 1853– 4 | Jan. 3, '54 | 13·5 |
| 1855 | 20 | 57·8 | 10, 11 | 24·5 | 33·3 | 15·8 | 46·2 | 31·9 | 39·1 | 1854– 5 | Feb. 19, '55 | 11·1 |
| 1856 | 31 | 58·0 | 30, 31 | 24·7 | 33·3 | 8·5 | 45·7 | 33·3 | 39·5 | 1855– 6 | Dec. 22, '55 | 16·9 |
| 1857 | 18 | 66·2 | 22 | 27·7 | 38·5 | 15·5 | 50·2 | 35·9 | 43·1 | 1856– 7 | Dec. 28, '56 | 18·5 |
| 1858 | 24 | 68·7 | 11 | 23·6 | 45·1 | 15·0 | 50·7 | 33·6 | 42·2 | 1857– 8 | Jan. 6, '58 | 20·9 |
| 1859 | 5 | 63·5 | 31 | 28·9 | 34·6 | 17·0 | 54·2 | 40·5 | 47·4 | 1858– 9 | Nov. 24, '58 | 20·5 |
| 1860 | 28 | 59·5 | 10 | 23·5 | 36·0 | 21·0 | 49·2 | 35·0 | 42·1 | 1859–60 | Dec. 19, '59 | 14·0 |
| 1861 | 24 | 61·8 | 14 | 29·1 | 32·7 | 16·7 | 52·7 | 37·1 | 44·9 | 1860– 1 | Dec. 25, '60 | 8·0 |
| 1862 | 24 | 63·6 | 4 | 22·5 | 41·1 | 14·0 | 50·0 | 38·4 | 44·2 | 1861– 2 | Jan. 19, '62 | 20·4 |
| 1863 | 3 | 64·0 | 18 | 28·1 | 35·9 | 22·5 | 53·7 | 35·7 | 44·7 | 1862– 3 | Nov. 23, '62 | 24·8 |
| 1864 | 4 | 58·0 | 24 | 26·9 | 31·1 | 19·6 | 49·8 | 34·3 | 42·1 | 1863– 4 | Jan. 7, '64 | 14·3 |
| 1865 | 31 | 58·7 | 21 | 23·7 | 35·0 | 20·6 | 44·0 | 31·1 | 37·6 | 1864– 5 | Feb. 15, '65 | 15·5 |
| Mean 25 years, 1841–65 | .. | 62·2 | .. | 24·9 | 37·3 | 16·1 | 50·0 | 35·3 | 42·7 | .. | .. | 17·2 |

| Year. | March. Shade Temp. Max. Day. | Max. | Min. Day. | Min. | Range. | Grass Temp. Min. | Shade Temp. Monthly Mean. Max. | Min. | Max. and Min. | Winter. Lowest Shade Temperature. Year. | Date. | Lowest Temp. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° | | ° | ° | ° | ° | ° | ° | | | ° |
| 1866 | 30 | 64·0 | 1 | 22·5 | 41·5 | 16·2 | 48·4 | 34·5 | 41·5 | 1865– 6 | Mar. 1, '66 | 22·5 |
| 1867 | 24 | 59·1 | 16 | 24·5 | 34·6 | 18·5 | 44·5 | 33·0 | 38·8 | 1866– 7 | Jan. 5, '67 | 6·6 |
| 1868 | 27 | 58·5 | 30 | 28·1 | 30·4 | 21·0 | 52·9 | 36·8 | 44·9 | 1867– 8 | Dec. 9, '67 | 21·2 |
| 1869 | 5 | 53·6 | 8 | 27·3 | 26·3 | 20·4 | 44·8 | 32·3 | 38·6 | 1868– 9 | Nov. 6, '68 | 26·1 |
| 1870 | 2 | 61·1 | 14 | 23·1 | 38·0 | 18·2 | 46·9 | 34·0 | 40·5 | 1869–70 | Feb. 11, '70 | 19·4 |
| 1871 | 24 | 70·9 | 15 | 28·9 | 42·0 | 21·4 | 55·0 | 36·7 | 45·9 | 1870– 1 | Dec. 25, '70 | 9·8 |
| 1872 | 7 | 60·8 | 26 | 26·1 | 34·7 | 19·9 | 53·5 | 37·7 | 45·6 | 1871– 2 | Dec. 8, '71 | 18·6 |
| 1873 | 29 | 64·6 | 14 | 27·2 | 37·4 | 18·2 | 51·3 | 35·2 | 43·3 | 1872– 3 | Feb. 24, 25, '72 | 25·0 |
| 1874 | 23 | 65·4 | 11 | 22·6 | 42·8 | 15·0 | 52·8 | 36·6 | 44·7 | 1873– 4 | Feb. 11, '74 | 21·0 |
| 1875 | 8 | 57·4 | 5 | 25·5 | 31·9 | 25·5 | 47·1 | 34·5 | 40·8 | 1874– 5 | Jan. 1, '75 | 18·2 |
| 1876 | 31 | 64·7 | 19 | 25·5 | 39·2 | 18·3 | 49·1 | 35·0 | 42·1 | 1875– 6 | Jan. 8, '76 | 17·4 |
| 1877 | 29 | 59·4 | 1 | 23·5 | 35·9 | 18·2 | 48·5 | 34·5 | 41·5 | 1876– 7 | Mar. 1, '77. | 23·5 |
| 1878 | 3 | 57·3 | 25 | 24·3 | 33·0 | 13·5 | 49·5 | 35·9 | 42·7 | 1877– 8 | Mar. 25, '78 | 24·3 |
| 1879 | 19 | 63·7 | 8 | 28·6 | 35·1 | 24·9 | 49·0 | 34·8 | 41·9 | 1878– 9 | Dec. 25, '78 | 12·2 |
| 1880 | 26 | 61·4 | 29 | 27·4 | 34·0 | 18·0 | 53·1 | 36·9 | 45·0 | 1879–80 | Dec. 7, '79 | 13·7 |
| 1881 | 16, 18 | 59·8 | 27 | 24·6 | 35·2 | 20·1 | 51·1 | 35·5 | 43·3 | 1880– 1 | Jan. 17, '81 | 12·7 |
| 1882 | 18 | 65·0 | 23 | 28·8 | 36·2 | 19·0 | 55·1 | 37·6 | 46·4 | 1881– 2 | Dec. 24, '81 | 21·6 |
| 1883 | 31 | 56·7 | 24 | 20·6 | 36·1 | 14·3 | 44·1 | 29·3 | 36·7 | 1882– 3 | Mar. 24, '83 | 20·6 |
| 1884 | 16 | 68·8 | 3 | 27·3 | 41·5 | 24·0 | 52·7 | 37·4 | 45·1 | 1883– 4 | April 23, '84 | 27·0 |
| 1885 | 20 | 60·2 | 15 | 25·2 | 35·0 | 20·5 | 49·0 | 32·5 | 40·8 | 1884– 5 | Jan. 22, '85 | 22·3 |
| 1886 | 19 | 64·1 | 17 | 20·3 | 43·8 | 17·2 | 47·3 | 33·5 | 40·4 | 1885– 6 | Jan. 7, '86 | 16·5 |
| 1887 | 27 | 57·2 | 13 | 22·1 | 35·1 | 14·6 | 45·3 | 31·2 | 38·3 | 1886– 7 | Jan. 2, '87 | 15·5 |
| 1888 | 10 | 56·5 | 2 | 25·4 | 31·1 | 19·8 | 44·4 | 33·0 | 38·7 | 1887– 8 | Feb. 2, '88 | 18·4 |
| 1889 | 24 | 60·0 | 4 | 18·7 | 41·3 | 12·3 | 48·7 | 33·4 | 41·1 | 1888– 9 | Mar. 4, 89 | 18·7 |
| 1890 | 28 | 68·8 | 4 | 13·1 | 55·7 | 8·6 | 51·5 | 35·8 | 43·7 | 1889–90 | Mar. 4, '90 | 13·1 |
| Mean 25 years, 1866–90 | .. | 61·6 | .. | 24·4 | 37·2 | 18·5 | 49·4 | 34·7 | 42·1 | .. | .. | 18·6 |
| Mean 50 years, 1841–90 | .. | 61·9 | .. | 24·7 | 37·2 | 17·3 | 49·7 | 35·0 | 42·4 | .. | .. | 17·9 |

Tables II. III. and IV. give the hourly values of temperature, pressure, and wind obtained from the continuous records. The absolutely lowest temperature occurred at 6.50 a.m. on the 4th, both at Kew and Falmouth, and was said to be shortly before 7 a.m. at Greenwich. It will be seen that the air was very dry at all three observatories for some hours before and after the period of greatest cold, also that the fall of barometer which was in full progress at the commencement of the 4th, due to the southerly movement of the high pressure system and the incoming influence of the approaching cyclonic disturbance, was checked about the time of maximum cold, and a slight temporary rise is shown at each observatory; this movement is equally well marked after applying the diurnal range correction. The wind observations show a calming down of the atmosphere, the movement of the air being almost imperceptible for a few hours when the temperature was at its lowest. The latter feature is by no means uncommon during periods of very low temperature, and is doubtless intimately associated with intense radiation. In the present case, however, the terrestrial radiation was exceptionally small, a fact which was very prominently noticed by several observers. The hourly values certainly seem to point to a descending current of air, but proof of this is by no means easily secured.

At Greenwich the thermometer in the shade registered 18°·1 on the 4th, which has only once been equalled in March during the last 100 years, a precisely similar reading having occurred on March 14th, 1845. During the last half century the temperature in March has previously fallen below 20° in three years only, whilst, during the whole winter, so low a temperature as 18°·1 has only occurred in eight years.

On the grass, exposed to the sky, the thermometer at Greenwich fell to 8°·6, which is lower than in any March since 1856.

An unusually high temperature also occurred at Greenwich during March, the shade thermometer registering 68°·8 on the 28th, a reading which has only been exceeded in March on two days during the last 50 years. The range of temperature at Greenwich, which amounted to 55°·7, was larger than in any March during the last half century.

Table V. gives the Greenwich temperatures during the last half century for March, as well as the lowest shade temperatures for each winter.

I would, before closing this paper, thank Mr. Scott and the Meteorological Council for allowing me free use of the information in the Meteorological Office, also Mr. Marriott and the Royal Meteorological Society for the use of its valuable returns. I would also acknowledge the ready assistance given by Mr. Symons, and by all who have so cordially assisted by the prompt supply of their observations.

## DISCUSSION.

Surgeon-Major HALE inquired whether Mr. Harding could mention a possible or probable cause of the very low temperatures recorded in Surrey, as from its southerly position the cold might reasonably be expected to be less severe there than in more northern localities.

Mr. ROSTRON remarked concerning Dr. Hale's inquiry, that possibly the low temperatures experienced in Surrey were due to the natural configuration of the district. His house at Beddington, where a minimum temperature of 5° was registered, was situated close to the river Wandle, running East and West, and laid low. The soil was chalk. One feature in connection with the weather experienced during the month was the extraordinary range of temperature, the difference between the extreme temperatures recorded being 62°. He should like to know whether so large a range had ever been observed in any other month.

Mr. GASTER said it was a comparatively easy matter to explain the meteorological conditions over the British Isles which caused the spell of cold weather as felt over the kingdom generally at the commencement of March: but the extreme cold experienced in certain parts of Surrey and Norfolk did not admit of easy explanation, and in fact he could not at present pretend to account for the severity of the frost in those districts at all. He proceeded to illustrate on the blackboard the distribution of pressure over Scotland and England during the first four days of March, and described in detail the progress Southwards of the anticyclone from day to day, showing how these changes had produced the frost experienced over the country at large on the 3rd and 4th. An examination of the thermograms from the Glasgow Observatory during this period proved that on the 3rd, under the influence of an incoming Westerly breeze, the temperature rose from about 25° at 6 a.m. to 39° by about 1 p.m.: during the following night the air maintained this temperature, there being hardly a degree of variation throughout the night, while over England, where Easterly breezes or anticyclonic air still held, the thermometer fell fast. But the difficulty was to explain why, just in certain limited portions of the South-east of England, such exceptionally low readings should have been recorded. Terrestrial radiation was slight, so the extreme cold could not have been due to that cause. He could only surmise that some down-draught of air might have occurred locally and produced the intense cold, but of this there was at present no evidence before the Society.

Dr. MARCET said that on reaching his house in Wimbledon Park on Tuesday, March 4th, about 11.30 p.m., he went to his thermometer screen and found the temperature was, as far as he recollected, 23°. The next morning the minimum thermometer indicated 13°·8, showing that the minimum must have occurred sometime between midnight and sunrise. He had frequently observed the temperature to be lower about 8 or 9 p.m. than at 11 or 12 p.m. the same night. The maps illustrating Mr. Harding's paper showed that the sea-side stations were much warmer than those inland. He should like to know whether Mr. Harding had any records of the temperature of the sea on the South and East coasts, and also whether sea-fog was prevalent on the morning of the 4th, as there must have been considerable difference between the temperature of the sea and the temperature of the air.

Mr. SYMONS said that respecting the area of greatest cold, he had been very much surprised, when investigating the frost of 1867, to find how severe that frost was in the Thames Valley. The frosts of 1838, 1860, and 1867 were all very severe in the same district. It would be interesting if observations concerning the changes of wind at Greenwich Observatory or elsewhere in March 1890 could be given, as evidence might thus be obtained of any down-draught of air, such as mentioned by Mr. Gaster.

Mr. SOUTHALL remarked that Mr. Symons appeared to class the frosts of 1860 and 1867 together. Possibly in the Thames Valley these frosts may have been similar, but the frost of 1860 was the much more severe of the two in the Wye valley. On March 13th, 1845, the Wye was frozen over at Ross; a phenomenon which does not occur once in a space of 50 years. A fair was held at the time, and it was stated that icicles a foot long hung from the animals' mouths.

Mr. BAYARD said that on January 7th and 8th, 1886, during a similarly cold period in this same district in Surrey, some very low temperatures were registered. The figures were printed in *Symons's Monthly Meteorological Magazine* for 1886, p. 11.

Mr. TRIPP remarked that some years ago, when in South Africa, he had made observations of air temperatures at two adjacent stations, one situated on a hill, and the other in a valley; and had found that the extremes recorded were much

greater in the valley than they were on the hill, while the means were much the same.

Mr. DINES inquired if there was any record of the depth of snow on the ground, as he thought these low temperatures generally occurred in the deep snow. At Hersham the temperature fell to 18°·8, but there was no snow, and this low temperature struck him as being very remarkable.

Mr. ROSTRON said that at Beddington there were two inches of snow on the ground.

Mr. MARRIOTT said he was much struck, when reading his instruments on the mornings of the 3rd and 4th, with the very little difference between the temperature of the air and that on the grass; and he did not think that the low temperatures recorded were due to radiation. There was no wind in the neighbourhood of London, but in the north a strong wind was blowing. Regarding Mr. Southall's remarks concerning icicles hanging from a horse's mouth, Mr. E. J. Lowe told him that during the winter of 1860 he had seen icicles of considerable length suspended from a horse's mouth.

Rev. G. T. RYVES gave particulars of the temperatures recorded at Tean, Staffordshire, during this cold period, and remarked that the most interesting point in connection with this frost was to explain why the extreme cold occurred where it did.

Mr. SOUTHALL inquired whether the effect of the low temperatures on vegetation was very marked.

Mr. ROSTRON said that he had noticed that Evergreens in the neighbourhood of Beddington were much shrivelled: Euonymus severely; Roses, Evergreen Oaks, Portugal Laurels badly, and even Yews were touched.

Mr. C. HARDING in reply said that respecting the cause of the extreme cold over parts of Surrey and Kent, he was inclined to the opinion that it was due to a down-draught of air. The whole district affected lay between the Easterly current of the anticyclone and the Westerly current of the cyclonic system to the North and West; the air being comparatively calm in the locality of the severe temperature. He hoped that the hourly readings from Greenwich, Kew, and Falmouth, which are given in the Paper, might help forward some explanation of the cause of the intense cold. Regarding the time at which the extreme temperature took place, Mr. Mace, at Tenterden, remarked that the greatest cold occurred at about 6 a.m., men who were out of doors stating that before that hour the air was not nearly so keen. He had hoped to make a comparison between the frost in March 1845 and that recently experienced. Mr. Glaisher had stated that the temperature experienced in 1845 was unprecedented. He had not been able to look into the question of sea temperature, but with regard to the condition of the sky during the period, the 3rd was clear, while the 4th was cloudy. He was surprised to hear that no snow remained on the ground in the neighbourhood of Esher, as in the suburbs of London the snow remained until well after the frost.

# THUNDERSTORM & WHIRLWIND AT YORK,

## SATURDAY, MARCH 8th, 1890.

By J. E. CLARK, B.A., B.Sc.
(Communicated by R. H. SCOTT, F.R.S.)

(Plate V.)

[Read April 16th, 1890.]

THE weather during the morning of March 8th had been rather unsettled, but without rain, and at noon showed sufficient signs of improvement for us to plan an afternoon expedition. Towards two o'clock, however, a heavy cloud began to gather in the North-west, and, soon after, thunder was heard. Approaching rather rapidly, rain began between 2.15 and 2.30, in the locality where I reside (I.).[1] This is on the outskirts of York, 600 yards due north of the Minster Chapter House (VIII.).[1] Soon hail began to fall, as the flashes became frequent and near; although they were not very vivid nor was the thunder very loud.

The hailstones came very thickly for 5 or 10 minutes, in some cases being as large as hazel nuts. The wind, West-by-north, was only strong enough to blow them in about $2\frac{1}{2}$ or 3 feet at a doorway $7\frac{1}{2}$ feet high. The hail outside was quite soft, the hard core being surrounded with irregular, snow-like masses, in a state of semi-slush. Enough fell here just to whiten the ground. The fall is said to have been heavier and the stones larger in the central and southern parts of York, especially in Parliament Street. There, however, the weekly uncovered market made it so unwelcome as to produce exaggeration. The size was given " as big as one's thumb."

Although there is no rain-gauge in the central parts, the amount did not probably vary very much, as the following totals indicate. The order is from North to South :—

| | | From Minster Chapter House. | Rainfall. Ins. |
|---|---|---|---|
| II. | Bootham School gauge ... | 1,400 ft. 50° W of N | 0·17 |
| III. | Museum gardens ,, ... | 1,300 ft. 110° W of N | 0·15 |
| IV. | Cherry Hill ,, ... | 3,450 ft. 175° W of N | 0·18 |
| V. | Mount School ,, ... | 5,150 ft. 150° W of N | 0·17 |
| VI. | Mount Villas[2] ,, ... | 8,300 ft. 155° W of N | 0·17 |

[1] These numbers refer to references on the map (Plate V.). Roman numerals to points in the City. Plate V. is a reproduction of the Ordnance Survey Map on a reduced scale.

[2] These numbers also include slight falls later in the day.

During the storm it grew very dark, yet not so as to make lights necessary. The cloud passed over to the South-east, we being apparently on its North-eastern fringe. The lightning was nearer on the South of York. Two of our boys, from Bootham School, were returning up the steep bit of hill from the race-course to the Mount (VII.), when a vivid flash was accompanied by simultaneous thunder, "which quite made me," says the writer, "feel funny." It "struck a pool of water about 4 feet in front of us, and sent the water aside to right and left." I should judge that the main flash was more distant, the splash being due to one of its ramifications along the drenched highway.

The storm was equally violent in other parts of the East and West Ridings. I noticed limbs off two trees near the point where the North Eastern Railway crosses the Wharfe at Bolton Percy. At Dewsbury it attracted considerable attention, and it has been reported to me from Rawdon, near Leeds, and from Bradford, where it occurred at 2 p.m., or about half an hour sooner than at York. At Huddersfield, too, the record was "thunderstorm from 2 p.m." At Driffield, 28 miles East-by-north, occurred "Heavy thunder overhead at 3.25 ; squall of wind and rain from West-north-west at 4.15 ; force 5."

At my house all was practically over at 2.45, and there were at first signs of the afternoon clearing, although rather a strong South-westerly breeze was now blowing. The wind, however, came at times in very strong gusts, often accompanied with slight showers, from a little South of West.

Of the "whirlwind" I did not hear before Monday, and could not go to see any of its effects until three weeks later. Since then I have examined its course, except just at Water Fulford, and after it had crossed the long approach to Tilmire Common. Some of our boys[1] kindly investigated its track East of the Ouse on half-holiday afternoons, by aid of a tracing from the 6-inch Ordnance map.

A fairly correct account is given in the *Yorkshire Herald*, March 10th. The *Yorkshire Chronicle* mentions that, at Heslington, a woodshed belonging to Mr. Hills was blown down.

Outside the narrow track no damage whatever appears to have been done near York. The time was given me by the Head Gardener at Bishopthorpe as 2.40 or 2.45 p.m. Both he and Captain Key, at Rose Hall, Water Fulford (*vide infra*), noted that it was during the thunder and lightning. As Bishopthorpe is 3¼ miles South-by-west from my house, the course of the thunderstorm makes this agree with the time when it would be drawing to a close.

The gardener informed me that the wind had begun to rise some five

[1] Egbert C. Morland, after preliminary surveys on the 10th, went over the ground from "38" to "75" on the 12th, with C. H. Merz. On the 15th F. G. Fryer and A. Beale worked backwards from Heslington ("110" to "79"). W. Stephens noticed "37" on the 8th, an hour after the storm, but did not see the havoc across the river! J. H. Fryer and E. C. M. noted "111" and "112" on the 19th; on the 26th J. P. J. Malcomson and L. Baker took a few photographs. I have examined Nos. "1" to "37" and "55" to "93"; also "38" to "54" from across the river, except "48" to "51."

minutes before, and that there had already been some strong gusts. He was just outside his back-door, looking North over the Archbishop's kitchen gardens. So deafening was the rush of wind that he was not aware until after, of the destruction of two magnificent elms, not 80 yards away, nor of the branches torn from other trees along the road-side on his right, and in sight of him.

On April 2nd, Mr. Richard Thompson called upon Capt. W. H. Key, of Rose Hall,[1] 4,800 ft. East-north-east from this cottage. He was with his foreman in the fields near by. They had taken shelter in a strongly-built hut, within 100 yards of four of the shattered trees, yet nothing was heard except the wind.

According to the gardener the gust lasted about half a minute. "It was over before we had time to be frightened, or run out to see what it was," said the good woman of a cottage near Rose Hall.

The first undoubted signs of damage are at a point nearly South-south-west (155° W of N) from the Minster Chapter House, and exactly 3 miles away. The cyclone ended 2¾ miles to the South-east-by-east (120° E of N), having travelled 3⅝ miles, measured in a straight line, from West-south-west to East-north-east (69° E of N). Slight detours make its whole track about 4¼ miles in length.

Two hundred yards West-south-west of the first barn is a small plantation. From this, possibly, a few small larch branches were torn off; but, as woodmen had been at work, it was difficult to be certain. Copmanthorpe lies just a mile further westward. Here there are no signs of any damage.

The course of the storm to the Archbishop's grounds, ¾ of a mile, is a straight line. Thence it swerved slightly northwards along the Ouse, affecting at first only the North bank of this North-east-by-east reach. Then, suddenly, two fields before Rose Hall, much damage began on the south bank. Its direction continued unchanged over Water Fulford.

Here the Ouse comes down from the North-west-by-north, making a bend of more than a right angle. The North-east-by-East line, however, is continued by a small stream or drain, 4 to 5 ft. wide, running to Heslington.

The storm continued up this to a point 1¾ miles from the gardener's cottage, and two fields short of the Tilmire approach. Here it seems to have been deflected, springing up again to the South-east; for only a few twigs are touched on a single tree in the next 300 yards, whilst two trees 400 yards to the South-east are much damaged. Tilmire appears to have been reached along this same line, 500 yards from the original direction. Towards this it now turned, or rather, perhaps, the storm was resumed over the whole of this width. It narrowed down again, however, while approaching Heslington, but here an apple-tree was damaged 400 yards North of the main line. Reaching the road to Langwith it ended its serious damage by untiling another barn (and seems to have turned South-east, following the

[1] I have also had some correspondence with and verbal information from him.—J. E. Clark.

road to the corner of "Langwith Long Lane," where a small bough was taken off a corner tree).

We come next to the more serious damage done by the storm, and the evidences of its strength and extent.[1]

The "barn" (1) (Plate V.) at which it began is now dismantled and roofless, its gables facing square to the storm. That at the South-west is under a well-grown oak. This tree was untouched, except in one or two small twigs, yet the gable-end of the barn was blown over. It formed a triangle of well-built brickwork, 18 ft. long, 7 ft. high, and 10 ins. thick. Nine hundred feet, almost due East of the barn, a few twigs were gone from an elm (9) between an untouched oak and ash, 35 yards apart. Nothing but small branches were touched on intermediate trees. The hedges, it may be noted, along the whole track are nearly all either parallel to or at right angles with the East-north-east storm-track.

In the next hedge, however, and nearly 100 yards East-north-east of (9), a large ash (10) was much wrecked. Four branches were off, one 39 ft. long and 1¼ ft. in diameter. Another, 16 yards North of it (11), was untouched, and so was a thorn 60 yards to the South. Here, then, the track must have been very narrow. So it was 2,300 ft. from the barn, where an oak (15) on the far side of the road was injured, whilst ash trees (14) 20 yards North and South on the other side, were untouched.

Crossing the next field, it uprooted a fine ash (16), 2½ ft. in diameter, and at the next hedge three ashes (17, 18, 19), the outer ones 50 yards apart, were affected. In the next field a row of ashes were injured, and one (22), being unsound, was snapped off, although 3 ft. across. Then came the greenhouse and gardener's cottage (25). The former lost a chimney and the latter a few tiles. Across the road, in the Archbishop's grounds (26), two grand elms went down on the Southern edge of the track, a plane tree close to the more Southerly elm being untouched. The next three to the North along the roadside lost their tops, while hollies, &c., in between, suffered, the whole width being 60 yards. Slight damage was done over yet another 30 yards (28) and more among the trees within the grounds (29).

As it followed Wall Ridge Reach of the Ouse, the little damage done at first was to ashes in a hedge 20 or 25 yards back from the right bank (31, &c.). Two fields before Rose Hall, however, on the left bank, a row of fine elms, almost North and South (38, 39, 40) suffered severely. Three next the river were uprooted, one of 4 ft. diameter and 80 ft. high. The last affected, 180 yards South of this one, was snapped off at 20 ft., where it was 2¼ ft. in diameter.

In this row was a rookery, and some rooks were actually killed by the falling branches, not being able to escape.

As the other bank of the Ouse was also affected the width of the storm track here must have been at least 250 yards, nor could it have been much less as it swept over the slight rise (of glacial clays and gravels) just at

[1] The positions of damaged objects are shown on the map, Plate V., by Nos. The positions of *undamaged* objects along the track of the storm are indicated by fainter Nos.

the river bend, on which Rose Hall is situate, with farm buildings and cottages. These, and the gardener's cottage above, are the only houses in the whole 4 miles, although the three villages of Bishopthorpe, Fulford and Heslington lay but 200 or 300 yards off the storm track.

Rose Hall (45) lost its South-east chimney and tiles. The inner North-east angle of the farm buildings beyond was untiled. Next, many stacks in the stack yard (49) were upset or scattered, the hay lodging in the trees to the East-south-east up to a height of 40 ft. Yet other stacks were most capriciously left untouched. A large and new Dutch barn (51) was turned over, landing the other side of the hedge. Just opposite here the barge of Mr. Palmer (47), under the North bank, broke from its stout moorings "as if they were cords," its little boat being swamped, whilst the barge itself rocked very much. Indeed the wind seems to have been as violent as anywhere in the half-mile between the above-mentioned elms and Dam Lands Lane. In the dip of the stream two ashes (58) and a splendid oak (55) were uprooted. The photographs exhibited to the meeting show this oak and an ash (57) near the other two, from which a bough 1 ft. in diameter was carried 50 ft. Others show a willow (41) near the great elms.

Many trees, especially willows, had the bark stripped off branches and twigs.

Crossing the field containing the great oak, we reach Dam Lands Lane, where were grouped (60) a barn, half untiled and blown askew, three shattered ashes and a demolished haystack, much hay from which was in the next two hedges, for a width of 50 yards. The storm seems to have contracted here to this width, and so to have remained until near the Tilmire Approach. Of over two dozen trees, injured in this ¾ mile section, none were snapped off or uprooted. Such began again upon its crossing the strip of common (89) and continued to Heslington (95, 100, 105, 110). One bough was blown right across the Common, 90 yards, into the opposite hedge.

Just before Tilmire Approach there was again a sudden development of activity to the South of the previous line of advance, so that the line of damage along its further hedge facing West-by-south is about 700 yards long. It again contracted towards the main line, but seems to have widened again at Heslington, spreading out to the North-east and South-east. After the barn (109) comes half a mile of treeless, newly-enclosed fields; beyond which fresh signs of damage have just been discovered.

Papers sent me by Mr. R. H. Scott show that the same, or simultaneous storms visited other counties on Saturday afternoon. Nottingham and Lincolnshire appear to have been affected about 1½ hours later, and Leicestershire 2½ hours later. Mr. C. J. Bromhead reports damage in Lincolnshire, especially the destruction of a windmill at Heckington. The wind velocity at Bidston, near Liverpool, at 2 p.m., was 34 miles per hour, West-south-west; "a high velocity for the station."

We come next to the barometric conditions. The 8 a.m. chart shows three depressions; 28·8 ins. North-west of Scandinavia, 28·8 ins. over Finland, and an approaching and increasing depression of 29·2 ins., or lower, North-west of Ireland. There were also two secondary depressions over the North Sea, and

apparently a third over, or South of, St. George's Channel. The high pressure area lay over the Pyrenees, 30·0 ins. Hence, naturally, the forecasts predicted "squalls, some rain."

At 2 p.m. (Fig. 1) pressure seems to have slightly increased over South-west France, and the three depressions had moved forward, that off Ireland giving 28·98 ins. as the reading at Malin Head. Pressures over England had decreased more than over the North Sea, where the isobars now bent northward. A well-marked secondary depression, of which the 8 a.m. chart gives no indication, lay North-west of York, the 29·2 ins. isobar curving sharply round on the South-south-east. A corresponding bend affects all the isobars from 29·1 ins. to 29·6 ins., their apices running in a curve from Dumfries, viâ York, Leicester, Oxford and Weymouth, to South of Land's End.

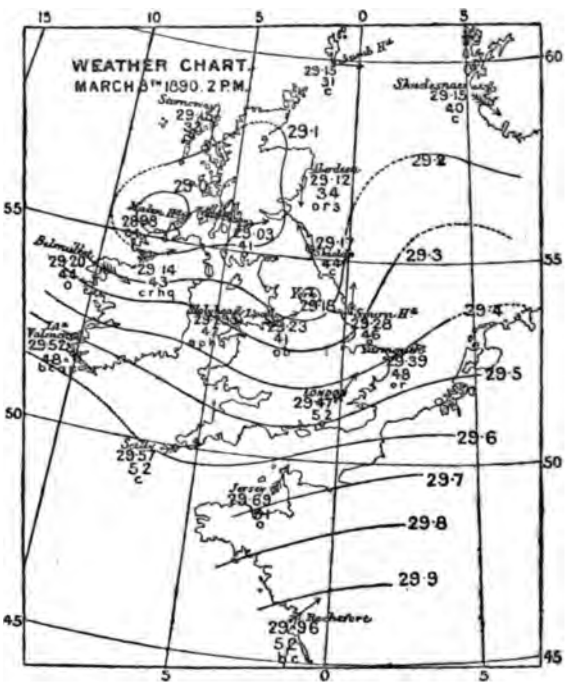


FIG. 1.

The secondary depression is well shown upon the accompanying 4 aneroidograms (Figs. 2-5). Taking that at York (which was about 10 minutes fast on the 8th), we see that a rapid fall during the morning was checked soon after 2 p.m., a slight rise occurring about 2.30. Then the fall continued until 3.30, when there was a yet more marked recovery, followed by a further slight fall until 10 p.m. At midnight there began a rapid and steady rise of over 0·9 ins. in 22 hours.

Three other barograms have been kindly supplied :—

(1.) Mr. C. L. Brook, of Meltham, near Huddersfield; scale 5 inches to the barometric inch and 4½ ins. to the day, clock right within 5 mins.; this is 88 miles South-west from York.

(2.) Messrs. Reynolds and Branson, Leeds; 28 miles South-west-by-west from York; scale 2 ins. and $2\frac{1}{10}$; judged by York and Huddersfield, it would *seem* to be at least an hour fast.

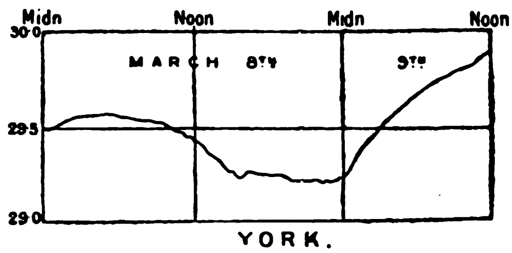


FIG. 2.

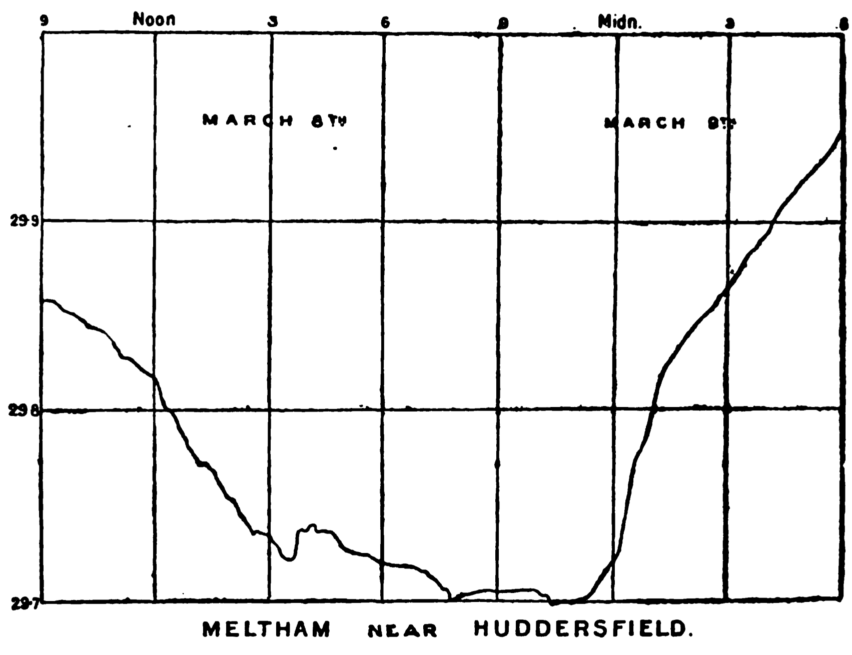


FIG. 3.

(3.) Mr. H. Mellish, Hodsock Priory, near Worksop; 46 miles South from York. Scale same as York (Richard Frères of Paris), 1 in. by 1¼ in.; corrections to mean sea level, —0·04 in. Clock a little fast.

They all bear a striking resemblance, showing the pause in the fall, the further fall, and sudden, almost perpendicular rise of 0·03 to 0·04 in.; a further gradual fall, soon after the cessation of which comes a very rapid, prolonged, steady rise of 0·9 to 1·0 in.

The splendid Huddersfield barogram shows some interesting details. At 2·30 is a sudden fall of about 0·006 in. with an almost immediate recovery, followed by a second fall of half the amount.

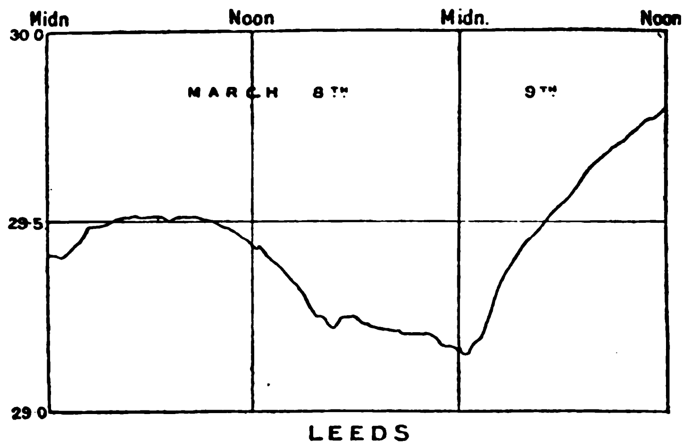


FIG. 4.

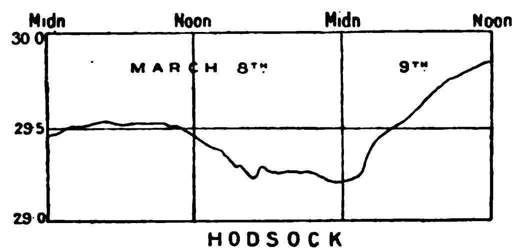


FIG. 5.

These came just an hour before the rise of 0·03 in., as was the case, too, at York very slightly later. The Worksop interval is also an hour, but comes a good hour later, or at 5 o'clock. Rev. W. C. Ley, at Lutterworth, 95 miles south of York, reports a "great jump" during the thunderstorm and violent hailstorm, which began at 5 p.m. If (which is unstated, however,) the interval between the storm and the jump was the same as at York and Huddersfield, the "jump" must have been a little after 6 o'clock, when it was "slowly clearing in the north-west." The "jump" was during a "wind swirl."

From all the data the storm seems to have stretched from North-north-east to South-south-west at least 50 miles, its northern extremity reaching rather North of York. Its line of advance, however, would seem to have been towards the South-east or South-south-east. The latter would bring its southern end over Lutterworth, and account for the heavy thunder at Driffield at ¾ of an hour later than at York. The advance may, perhaps, have followed the isobar down-curves already described.

The "whirlwind" at York resembled rather a remarkably strong squall, perpendicular to this line of advance. There are no definite signs of a real *whirl*, except that most damage was done along its southern edge; curiously, also, branches on the southern side of trees seem to have suffered worst, and any sudden accession of width came on the same side. As a fact, although Captain Key speaks of it as more violent than any wind he ever felt, its force was not very great for a real whirlwind; it nowhere levelled *everything* before it. Its capricious action is very striking. In one case, Captain Key says, a tree facing the storm was untouched, whilst one *behind* it was uprooted. Its connection with the violent cloud-changes, common in thunder-clouds, is interesting. "It appeared to me," writes Captain Key, "as if two angry thunder-clouds met over the Archbishop's Palace at Bishopthorpe (1,300 ft. South-west-by-west from his position), one coming from the South, the other from the North-west." Then "there was a sort of roar," the hut trembled, and all was over in less than a minute. Lightning flashes were noticed both before and behind in the line of the storm, and it darkened perceptibly.

At York, judging from the 2 p.m. chart, the storm was in the customary South-eastern octant of the main depression and of the minor depression as well, and occurred everywhere about an hour before the centre of the latter traversed the district. By 6 p.m. the main depression was near Glasgow, and had slightly filled up. Next morning it was at Christiania; pressure, as said, had rapidly recovered over England, where clear, cold weather prevailed, with moderate North-westerly breezes.

## DISCUSSION.

Mr. MARRIOTT gave an account of the great American Tornado of March 27th (p. 187).

Mr. SYMONS said that the account of the whirlwind near York showed that the structural damage done was due to the expansion of air within the buildings as the wind passed over or near them, the barns being probably empty at this season of the year. He then made some remarks concerning American tornadoes, quoting an instance given in Ferrel's *Popular Treatise on the Wind*, illustrating the up-lifting power of these phenomena. He further said, concerning the force with which objects were hurled by the wind, that in the case of a whirlwind at Baldock he had found slates firmly embedded in the trunks of living trees.

Mr. SOUTHALL remarked that the expansion of the air theory would not apply in the case of damage to trees, which were often cut through, as if by an axe.

Mr. SYMONS said that he did not of course mean to say that all the damage done by a whirlwind or tornado was due to the expansion of the air, but that much of the damage to buildings was so caused. He could quote several instances in support of his statement, the case of a pair of houses damaged at

Walmer, in Kent,[1] being an especially good illustration of the outward force exerted by the air.

Dr. MARCET stated he was not quite prepared to accept Mr. Symons's theory that the damage caused to buildings was due to the expansion of the air inside.

Mr. TRIPP said that he had watched roofs being carried away by gales of wind, and had noticed that they were raised up and then dropped.

Mr. CLARK subsequently wrote to the Secretary:—

"In reference to the discussion on the whirlwind at York, I fancy Mr. Symons has misinterpreted the facts as to injury to barns. The mischief was done, rather, by the wind getting inside. Of course in the Dutch barn,—a roof on stilts,—there could be no outward pressure of the kind supposed.

"In reading Mr. H. A. Hazen's interesting papers on Tornadoes, now appearing in *Science*, I have been struck by numerous points of resemblance, this being indeed a tornado in miniature. Among these are (1) the meeting of two clouds to the South-west-by-west; (2) the overpowering roar, deadening the crash of falling trees; (3) the definite and narrow limits of width; (4) the rapidity of passage; (5) the association with a thunderstorm; (6) the position (as with most thunderstorms) in the South-east octant of the depression; (7) the absence of any *conclusive* proof of a true *whirl*; (8) the absence of any barographic sign of a sudden decrease of pressure. Possibly, also, the destruction of the windmill at Heckington, 70 miles South-east of York, and the distance of the main depression, 300 miles North-west, may be no accidental coincidences, with 'an hour or so later, another line . . . about 50 miles South-east of the first,' which itself develops 'two hundred to four hundred miles to the South-east of the centre of the general storm' (*Science*, *XV*. p. 270)."

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# On the possibility of Forecasting the Weather by means of Monthly Averages.

BY A. E. WATSON, B.A., F.R.Met.Soc.

(Abstract.)

[Read April 16th, 1890.]

MR. WATSON's idea in this paper is that the average values of meteorological phenomena are constant quantities, and that any variation from them is sure to be met by a compensating variation in the opposite direction.

The author has got out the averages for monthly mean temperature and rainfall for Croydon for 25 years, and has tabulated the divergence of each year from this average value in two columns, + and −. He finds that the number of + and − values is nearly equal, but not exactly so.

He then goes on to argue that if the deviation has been in either direction, positive or negative, for a number of years, the probability of a reversal of the sign of the deviation increases. He says: "The reverses will be of greater importance in proportion to the number of similar signs that have characterised this series of months," and he quotes instances.

His forecasts have been published in the two best local papers for some months, and the author declares himself to be highly satisfied with the results, some of which are detailed in the paper.

[1] *Meteorological Magazine*, Vol. XIII. (1878), p. 149.

DISCUSSION.

Mr. ROSTRON remarked that the last five Februarys have been abnormally cold, but immediately before that period they were abnormally warm. If the cold Februarys continued for some years they would of course restore the mean, but the question was how long would this reaction go on?

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# APPLICATION OF PHOTOGRAPHY TO METEOROLOGY.

## Eleventh Annual Exhibition of Instruments,

Held, by permission of the Council of the Institution of Civil Engineers, at 25 Great George Street, Westminster, S.W.

MARCH 18TH to 21ST, 1890.

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### PHOTOGRAPHIC METEOROLOGICAL INSTRUMENTS.

1. **Specimens of the Thermometer Tubes used in the Kew Pattern Thermograph,** and described in the *Report of the Meteorological Council of the Royal Society* for 1867. *Exhibited by the* METEOROLOGICAL COUNCIL.

2. **Scale and reading glasses for tabulating Barograms.**
*Exhibited by the* METEOROLOGICAL COUNCIL.

3. **Scale for tabulating Thermograms.**
*Exhibited by the* METEOROLOGICAL COUNCIL.

4. **Chemical Photometer devised by Sir H. Roscoe, M.P., F.R.S.** By means of this instrument a strip of paper is so exposed to daylight that the time requisite to produce a definite chemical effect can be calculated to seconds. The exposure of the paper is effected by pasting pieces of standard sensitive paper upon a band, and inserting this into a thin metal slide having a small opening at the top furnished with a cover, which can be made instantly to open or close the hole under which the sensitive paper is placed. (First Pattern, 1863.)
*Exhibited by* THE KEW COMMITTEE.

5 **Experimental Instrument for Recording the Intensity of Daylight,** the results being obtained by causing a disc of sensitized paper to revolve behind a screen with a rectangular aperture. *Exhibited by* J. B. JORDAN.

6. **Jordan's Sunshine Recorder.** First Pattern (March 1885.) This instrument consists of a cylindrical box, on the inside of which is placed a slip of cyanotype paper. Sunlight being admitted into this box by three small apertures, is received on the paper, and travelling over it by reason of the earth's rotation, leaves a distinct trace of chemical action.
*Exhibited by* J. B. JORDAN.

7. **Jordan's Sunshine Recorder.** Improved pattern. (November 1885.) In this instrument two apertures are used instead of three.
*Exhibited by* J. B. JORDAN.

8. **Jordan's Sunshine Recorder.** New pattern. (March 1888.) The improvement in this instrument over the others consists in using two hemi-cylindrical boxes, one to contain the morning and the other the afternoon record. An aperture for admitting the beam of sunlight is placed in the centre of the rectangular side of each box, so that the length of the beam within the chamber is the radius of the cylindrical surface on which it is projected; its path therefore follows a straight line on the paper at all seasons. The hemi-cylinders are placed with their diametral planes at an angle of 60°. *Exhibited by* J. B. JORDAN.

9 **McLeod's Sunshine Recorder.** This instrument consists of a glass sphere, silvered inside and placed before the lens of a camera, the axis of the instrument being placed parallel to the polar axis of the earth. The light from the sun is reflected from the sphere, and some of it, passing through the lens, forms an image on a piece of prepared paper within the camera. In consequence of the rotation of the earth, the image describes the arc of a circle on the paper, and when the sun is obscured this arc is broken. *Exhibited by* THE KEW COMMITTEE.

10. **Photo-Nephograph designed by Captain Abney, F.R.S.,** for the Meteorological Council, for the registration of the velocity and direction of motion of clouds. *See Reports of the Meteorological Council* for the years 1879 and 1881. *Exhibited by the* METEOROLOGICAL COUNCIL.

11. **Slide Rule designed by Gen. Strachey, F.R.S., for obtaining the height and distance of clouds** from the pictures yielded by the cloud cameras. *Exhibited by the* METEOROLOGICAL COUNCIL.

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## INSTRUMENTS NOT PREVIOUSLY EXHIBITED.

12. **Instrument for showing the velocity of the wind.** The shaft of an anemometer is connected with the shaft of the instrument, and in turning works the small centrifugal pump, thus raising the level of the mercury in the long cistern. The deflexion of the pendulum from the vertical position is proportional to the rate of turning, and thus gives a uniform scale. *Exhibited by* R. W. MUNRO, F.R.Met.Soc.

13. **Instrument for showing the pressure of the wind from a velocity anemometer.** The arrangement is the same as in the preceding instrument, but the fall of the float in the small circular cistern is proportional to the square of the velocity and therefore to the wind pressure, thus giving a scale of pressure with the divisions at uniform distances. *Exhibited by* R. W. MUNRO, F.R.Met.Soc.

14. **Trotter's Compensating Thermometer.** The bulb and scale are connected with a metal tube, which may have any length. In order to compensate for the various temperatures through which the tube passes, a second tube of equal calibre (called the compensator) runs by the side of the first; but, instead of having a bulb, it terminates in a sealed end, and is consequently affected only by the various temperatures through which it passes. The temperature is read off on the thermometer by a sliding index scale, the arrow point on the right being set to the level of fluid in the compensating tube, and the temperature being indicated on the opposite tube. *Exhibited by* J. LONG.

15. **Draper's Self-Recording Thermometer.** In this instrument a clock rotates a disc, on which is placed a chart, indicating by radiating divisions the hours of the day and days of the week, and gives by concentric circles the degrees of temperature from 20° below zero F. to 110° above. A lever provided with a pen is supported on an axis, carried by the expansion and contraction of bi-metallic strips, so that the pen which rests on the chart moves outward and inward from the centre, drawing a line on the surface of the chart, showing the temperature at any given time. *Exhibited by* J. J. HICKS, F.R.Met.Soc.

16. **Mercurial Minimum Thermometer,** with lens front.
*Exhibited by* J. J. HICKS, F.R.Met.Soc.

17. **Radial Scale Thermometer.**
*Exhibited by* J. J. HICKS, F.R.Met.Soc.

18. **Denton's Clinical Thermometer Case,** with new spring-catch. The slight strain on the spring (which forms part of the case itself) is only exerted when the lid is being put on or off, so that the spring retains its elasticity.
*Exhibited by* S. G. DENTON.

19. **Watkin Aneroid** in an aluminium case.
*Exhibited by* J. J. HICKS, F.R.Met.Soc.

## MODELS.

20. **Model of the Kew Self-recording Magnetographs.** The instrument, erected in 1857, is arranged to register photographically the variation of the position of a freely suspended Magnetic needle, as well as the intensity of the Horizontal and Vertical Forces acting upon it. A full description is given in the *Report of the British Association*, 1859.
*Exhibited by the* KEW COMMITTEE.

21. **Working Model to show the connection between the Monsoons and the currents of the Arabian Sea and the Bay of Bengal.**
*Exhibited by* A. W. CLAYDEN, M.A., F.R.Met.Soc.

22. **Model of whirling machine used at Hersham for testing anemometers** and for experiments on wind pressure. Scale ½ inch to the foot.
*Exhibited by* W. H. DINES, B.A., F.R.Met.Soc.

23. **Model showing manner in which the pair of Photo-Nephographs are mounted for use.**
*Exhibited by the* METEOROLOGICAL COUNCIL.

## PHOTOGRAPHS AND DRAWINGS OF INSTRUMENTS, &c.

24. **Description of Mr. T. B. Jordan's mode of photographically registering the indications of Meteorological Instruments.** (*Report of the Royal Cornwall Polytechnic Society*, 1838.)
*Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

25. **Brooke's Photographic Self-Registering Magnetic and Meteorological Apparatus.** Description and illustrations.
*Exhibited by* W. MARRIOTT, F.R.Met.Soc.

26. **Drawings of the Kew pattern Barograph and Thermograph.**
    1. Barograph. Cover removed.
    2. Thermograph. Indoor arrangement.
    3. Thermograph. Outdoor arrangement.

*Exhibited by* C. H. THOMPSON.

27. **Frame containing early autographic records of Magnetograph and Barograph** by the Daguerreotype process obtained at the Kew Observatory in 1849. *Exhibited by the* KEW COMMITTEE.

28. **Frame showing various early autographic records obtained at the Kew Observatory.** *Exhibited by the* KEW COMMITTEE.

29. **Engraved Copy of Photographic Record of Dry Bulb and Wet Bulb Thermometers by Old Thermograph** on February 16, 1849.
*Exhibited by* W. H. M. CHRISTIE, F.R.S., Astronomer Royal.

30. **Photographic Record of Dry Bulb and Wet Bulb Thermometers t Thermograph** on October 13-14, 1889.
*Exhibited by* W. H. M. Christie, F.R.S., Astronomer

31. **Three photographic views of the new Thermograph.**
*Exhibited by* W. H. M. Christie, F.R.S., Astronomer

32. **Photographic Record of Barometer on September 2-3, 1889.**
*Exhibited by* W. H. M. Christie, F.R.S., Astronomer

33. **Photographic Record of Atmospheric Electricity by Thomson's E meter** on March 16-17 and July 11-12, 1889, and on February 23- March 4-5, 1890.
*Exhibited by* W. H. M. Christie, F.R.S., Astronomer

34. **Four Photographic views showing the positions of Meteorologi struments at the Royal Observatory, Greenwich, 1890.**
*Exhibited by* E. E. McCl

35. **Photographic Barograms showing the barometric oscillation due Krakatoa eruption, August, 1883.** The stations shown are B Mauritius, Aberdeen, Valencia, Toronto, and Melbourne.
*Exhibited by the* Meteorological Cc

36. **Selection of Barograms and Thermograms.**
1. Passage of depressions or storm centres.
2. Sudden Changes of Temperature.
3. Changes of Temperature and Pressure during a Thunderst Kew, at 4 p.m. May 8th, 1871.
4. Thermogram. A Summer's day. Kew, August 13th, Difference between dry and wet at 5 a.m., 0°·5; at 2 p.m., 22°·7.
5. Thermogram, showing remarkable variations of hygrometri ditions, Aberdeen, August 12th, 1878. Difference between dry a at 2 p.m., 8°·9; 3 p.m., 4°·6; 4 p.m., 4°·3; and 5 p.m., 10°·3.
6. Oscillation of the barometer at Falmouth, January 29th, 6 p.m., to 30th, 8 a.m. Temperature and wind direction are shc comparison. *Exhibited by the* Meteorological Co

37. **Traces of the Curves from the Self-recording Instruments at th** cliffe Observatory, Oxford, showing a remarkable disturbance morning of March 8th, 1889. (By permission of the Radclif server.) *Exhibited by* F. A. Bellamy, F.R.M

38. **Curve showing the relation between the pressure and velocity wind.** *Exhibited by* W. H. Dines, B.A., F.R.M

39. **Curve showing the normal component of the wind pressure u sloping surface,** one foot square, the normal pressure being ta 100, and the pressure at various angles of inclination being ex proportionately. *Exhibited by* W. H. Dines, B.A., F.R.M

40. **Photographs of experimental apparatus designed for the reduc Cloud Pictures.** *Exhibited by the* Kew Comm

41. **Photograph of the Pole Star Recorder** in use at the Harvard ( Observatory, U.S.A., for registering the cloudiness during the (see p. 188). *Exhibited by* Prof. E. C. Pick

42. **Photographs of Aitken's Dust Counters.**—1. Showing Mr. Aitk serving with the instrument for use about the hill outside the Ben Observatory. 2. Instrument for use inside the Observatory, witl connecting it with the free atmosphere.
*Exhibited by* A. Buchan, M.A., F.

43. **Two Albums containing the Photographs of the Stations of the Meteorological Society,** taken by Mr. W. Marriott during the tions, 1884-1889. *Exhibited by the* Royal Meteorological Sc

44. **New England Meteorological Society's Exhibition,** January 1889. Two Views. *Exhibited by* A. L. ROTCH, F.R.Met.Soc.

45. **Photograph taken from the Sydney Observatory,** showing the thermometer shed, evaporator, solar thermometer, &c., in foreground. *Exhibited by* H. C. RUSSELL, B.A., F.R.S.

46. **The Seismograph** in use at the Sydney Observatory, New South Wales. *Exhibited by* H. C. RUSSELL, B.A., F.R.S.

47. **Diagrams showing the rise and fall of the Tides on the River Thames** from February 24th to March 3rd, 1890, as recorded by Adie's Tide Gauge at North Woolwich and Deptford. The unusual tide on February 28th rose 2¼ hours before its time, then fell, and 2 hours after rose again. *Exhibited by* P. ADIE.

48. **View taken at the Meglis Alp on the way to the Säntis Observatory, Switzerland,** September 7th, 1888. *Exhibited by* R. H. SCOTT, M.A., F.R.S.

49. **Map of the Environs of Sion House in 1635.** The present Kew Observatory is erected on a part of the area. *Exhibited by* F. GALTON, F.R.S.

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## PHOTOGRAPHS OF METEOROLOGICAL PHENOMENA, &c.

50. **Photographic Scale showing Intensity of Sunlight during Solar Eclipse, July 18th, 1860.** *Exhibited by* G. J. SYMONS, F.R.S.

51. **Photographs of Clouds** taken at the Observatory, Boulogne sur Seine France. *Exhibited by* MONS. PAUL GARNIER.

52. **Photographs of Clouds** taken at the Specula Vaticana, Rome. *Exhibited by* PADRE F. DENZA.

53. **Photographs of Clouds.** *Exhibited by* A. W. CLAYDEN, M.A., F.R.Met.Soc.

54. **Photographs of Cirrus Cloud** reflected from the surface of the Lake of Sarnen, August 1888. *Exhibited by* DR. A. RIGGENBACH.

55. **Thunder Clouds,** Northamptonshire, July 1887. *Exhibited by* DR. DREWITT.

56. **Photograph taken at Sea.** Strato-cumulus cloud in front of full moon. This illustrates the frequent error of artists drawing the moon to subtend an angle of arc larger than in Nature. *Exhibited by* DR. J. L. GREEN, F.R.Met.Soc.

57. **Photographs of Fog,** taken from the top of the Worcestershire Beacon, above the general level of the fog, which covered the whole of the surrounding country, January 12th, 1888. *Exhibited by* Messrs. NORMAN MAY AND CO.

58. **Sunset as seen from the Summit of Ben Nevis.** *Exhibited by* G. J. SYMONS, F.R.S.

59. **Clouds, Alvona Bay, Dalmatia, September 29th, 1889.** The mountains range from 3,000 to 6,000 feet. *Exhibited by* C. HARRISON.

60. **Sunsets at Mitcham.** Two views. *Exhibited by* K. MCKEAN.

61. **Frame containing specimens of Cloud photographs and Sun pictures.** *Exhibited by the* KEW COMMITTEE.

62. **Photograph and Enlargement of Cumulus Cloud,** taken by Mr. W. Friese Greene at Bath. *Exhibited by* G. T. GWILLIAM, F.R.Met.Soc.

63. **The Tail of an ordinary Cyclone.** Photograph taken at the Sydney Observatory, New South Wales. *Exhibited by* H. C. RUSSELL, B.A., F.R.S.

**ornado Cloud,** Jamestown, Dakota, June 6th, 1887. Two Views. The cloud funnel was 12 miles to the north. *Exhibited by* H. P. Curtis.

**Tornado Cloud.** Taken in the storm of June 22nd, 1888, showing the spiral-shaped funnel trailing at a considerable altitude in the air at the other side of a Lake, New Hampshire. *Exhibited by* H. P. Curtis.

**Photographs showing the Devastation caused by the Tornado at** Rochester, Minnesota, on August 21st, 1883. *Exhibited by* H. P. Curtis.

7. **Stereoscopic Views of the Devastation caused by the Tornado at** Grinnell, Iowa, on June 17th, 1884. *Exhibited by* H. P. Curtis.

68. **Damage by the Tornado which passed across the Isle of Wight,** from Brightstone to Cowes, September 28th, 1876. Four views. *Exhibited by* G. J. Symons, F.R.S.

69. **Snow View** in the Garden of the Bellerive, Zürich. *Exhibited by* W. Ellis, F.R.Met.Soc.

70. **Photographs of Alpine Storm and Snow Effects** taken by Mons. Gabriel Loppé. *Exhibited by* G. W. Freshfield, F.R.G.S.

71. **Photograph of Snow Scene taken by Moonlight** at Felton Park, Northumberland, January 1881. *Exhibited by* T. J. Murday.

72. **Snow Scenes,** Boston, U.S.A., Winter 1885. Two Views. *Exhibited by* H. P. Curtis.

73. **Ice Blockade and Frost Work,** U. S. Signal Service Station, Mount Washington, New Hampshire, during the winter of 1885. *Exhibited by* H. P. Curtis.

74. **Photographs showing thick Rime on trees** at Lincoln on January 7th, 1889. *Exhibited by* C. J. Bromhead, F.R.Met.Soc.

75. **Two Photographs of Hoar-frost.** 1. Showing how the front crystals grow outwards from a branch towards the direction from which the mist has been drifting. 2. Showing how the crystals settle on the edges of leaves. *Exhibited by* A. W. Clayden, M.A., F.R.Met.Soc.

76. **Hardrow Scar.** Two views: first, Summer flow; second, Winter view, January 25th, 1881. The cone at the bottom was a mass of frozen spray, firm to walk upon, but a stick could be pushed down into it. The cone was about 30 feet high. The upper part was a hollow icicle, semi-transparent, down the centre of which the water could be seen falling and passing into the cone below, which was opaque. *Exhibited by* G. J. Symons, F.R.S.

77. **Icicles near Aysgarth Middle Force, February 10th, 1887.** Weather very bright and cloudless, severe hoar-frost, minimum temperature 16° no snow. *Exhibited by* Rev. F. W. Stow, M.A., F.R.Met.So

78. **Mill-Gill, near Askrigg, March 4th, 1889,** after several days of seve frost. Minimum temperature 11°. *Exhibited by* Rev. F. W. Stow, M.A., F.R.Met.S

79. **Aysgarth Vicarage, Meteorological Station,** March 1890. *Exhibited by* Rev. F. W. Stow, M.A., F.R.Met.

80. **Snow Drifts at Southgate,** after the great Storm of January 18th, 188 *Exhibited by* W. Marriott, F.R.Me

81. **Ben Nevis Observatory in Winter.** Seven views. *Exhibited by* G. J. Symons,

82. **Niagara in Winter.** *Exhibited by* G. J. Symons,

83. **Trees broken by Rime Frost, near Castle Rising,** January 7th, 1889. Three views. *Exhibited by* C. B. PLOWRIGHT, F.L.S.

84. **Photographs showing the extent of the floods on the Severn** at Worcester, May 15th, 1886. *Exhibited by* G. B. WETHERALL, F.R.Met.Soc.

85. **Photograph showing Railway Bridge between Bransford and Henwick, destroyed by the Flood on the Teme,** May 14th, 1886. *Exhibited by* G. B. WETHERALL, F.R.Met.Soc.

86. **Flood at Rotherham Railway Station, May 15th, 1886.** Two views. *Exhibited by* E. M. EATON, F.R.Met.Soc.

87. **Flood at Chelmsford, August 2nd, 1888.** Series of eleven photographs taken before 10.30 a.m. *Exhibited by* G. J. SYMONS, F.R.S.

88. **Flood at Bristol, March 9th, 1889.** Two views: Broadmead and King Street. *Exhibited by* G. J. SYMONS, F.R.S.

89. **Flood at Hereford,** Midland Railway Station. *Exhibited by* G. J. SYMONS, F.R.S.

90. **Aysgarth Force, July 26th, 1888.** There had been a heavy thunderstorm on the previous day, but the flood had considerably diminished. *Exhibited by* REV. F. W. STOW, M.A., F.R.Met.Soc.

91. **A Winter Flood.** Aysgarth Middle Force, November 28th, 1888. *Exhibited by* REV. F. W. STOW, M.A., F.R.Met.Soc.

92. **After a Thunderstorm.** Aysgarth Upper Force, June 3rd, 1889. *Exhibited by* REV. F. W. STOW, M.A., F.R.Met.Soc.

93. **Photographs of Flashes of Lightning** sent to the Royal Meteorological Society since March 1889 by :—

Mr. H. J. Adams, Beckenham.
Mr. A. W. Bates, Putney
Messrs. Blanchard and Lunn, Cambridge.
Mr. A. W. Clayden, Tulse Hill Park.
Mr. J. R. Ellis, Cambridge.
Mr. R. H. Gill, Woodside Park, N.
Mr. A. Godman, St. Albans.
Mr. E. A. Golledge, Ilford.
Dr. Hoffert, Ealing.
Mr. J. F. Honeyball.
Mr. E. E. McClellan, Greenwich.
Mr. L. Medland, North Finchley.
Mr. A. W. Nicholls, Peterborough.
Mr. G. J. Ninnies, Balham.
Mr. J. Porter, Sydenham.
Dr. A. Riggenbach, Basle, Switzerland.
Rev. A. Rose, Cambridge.
Mr. A. Scrivenor, Southgate.
Mr. E. S. Shepherd, Westbourne Grove.
Mr. J. Stabb, Bayswater.
Mr. R. T. Stokes, Long Ditton.
Mr. J. L. Treadway, Crouch End, N.
Col. Tupman, F.R.S., Blackheath.
Prof. Weber, Berlin.
Mr. G. M. Whipple, Richmond.
Mr. J. W. Young, Croydon.

94. **Photographs of Electric Sparks,** explaining the Formation of Dark images of Lightning flashes. *Exhibited by* A. W. CLAYDEN, M.A., F.R.Met.Soc.

95. **Photographs of Electric Sparks** illustrating Mr. Clayden's explanation of the Dark images of Lightning flashes. *Exhibited by* S. BIDWELL, F.R.S.

96. **Photographs of oak tree split by lightning,** 5.30 p.m. June 6th, 1889; struck again and shivered, 1.30 p.m. June 7th, at Old Farm, Sachel Court, near Cranleigh, Surrey. Two Views.
*Exhibited by* CAPT. J. P. MACLEAR, F.R.Met.Soc.

G. J. SYMONS, F.R.S.
JOHN W. TRIPE, M.D. } *Secretaries.*
WILLIAM MARRIOTT, *Assistant-Secretary.*

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# PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MARCH 19TH, 1890.

Ordinary Meeting.

HENRY F. BLANFORD, F.R.S., Vice-President, in the Chair.

DAVID BALFOUR, M.Inst.C.E., Myre Hall, Houghton-le-Spring;
WILLIAM BELK, M.Inst.C.E., Hartlepool;
Capt. GEORGE A. CHADDOCK, The Elms, Lea Bank Road, New Brighton;
WILLIAM SANTO CRIMP, Assoc.M.Inst.C.E., London County Council, Spring Gardens, S.W.;
GEORGE FELLOWS, Beeston Fields, Nottingham;
ARCHIBALD EDWARD GARROD, M.A., M.D., M.R.C.P., 9 Chandos Street, W; and
Capt. HERBERT E. RAWSON, 6 Cornwall Gardens, S.W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read;—

"A BRIEF NOTICE RESPECTING PHOTOGRAPHY IN RELATION TO METEOROLOGICAL WORK." By G. M. WHIPPLE, B.Sc., F.R.Met.Soc. (p. 141.)

"APPLICATION OF PHOTOGRAPHY TO METEOROLOGICAL PHENOMENA" By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 146.)

On the motion of the CHAIRMAN the thanks of the Society were given to the Exhibitors for the loan of their instruments, &c.

The Meeting was then adjourned, in order to afford the Fellows an opportunity of inspecting the Exhibition of Instruments, &c., illustrating the application of Photography to Meteorology, which had been arranged in the Library of the Institution of Civil Engineers (p. 179).

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APRIL 16TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., F.G.S., President, in the Chair.

THE MARQUIS OF GALLIDORO, Villa Gallidoro, Palermo; and
JAMES MALLET VEEVERS, Mayfield, Denton, near Manchester,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"THE COLD PERIOD AT THE BEGINNING OF MARCH, 1890." By CHARL[illegible] HARDING, F.R.Met.Soc. (p. 152.)

"THUNDERSTORM AND WHIRLWIND AT YORK, MARCH 8TH, 1890." By J. CLARK, B.A., B.Sc. (p. 169.)

"ON THE POSSIBILITY OF FORECASTING THE WEATHER BY MEANS MONTHLY AVERAGES." By ALBERT E. WATSON, B.A., F.R.Met.Soc. (p. 1

# CORRESPONDENCE AND NOTES.

"THE AMERICAN TORNADO OF MARCH 27TH, 1890." By WILLIAM MARRIOTT, F.R.Met.Soc.

THE great storm which passed over the United States and played such havoc had its origin in the Rocky Mountains somewhere near Utah, where it was first observed on the morning of March 26th. The lowest barometer reading was 29·60 ins. at Salt Lake City, surrounded by generally clear weather, except on the North and South Pacific Coast, where rain was falling. During the day the cyclone greatly increased in energy and magnitude, its influence being felt as far north as Montana, and its southern limit reached the Gulf of Mexico over Texas, snow beginning to fall in the north-west and rain to the eastward in Kansas. The wind throughout the surrounding country increased in force and blew towards the storm centre from all points at the rate of 20 to 24 miles an hour. The storm centre continued to move eastward, and by 8 a.m. on Thursday, the 27th, had reached Leavenworth, Kansas, where the barometer reading was 29·28 ins. The force of the wind for a radius of 500 miles from the centre averaged 36 miles an hour on the eastern side, and from 12 to 14 miles greater on the southern side, while on the western side the velocity was 60 miles an hour, with a severe "blizzard" raging in Nebraska and Wyoming, and a "norther" prevailing in Texas.

By noon the centre had reached the State of Illinois, the barometer reading at Springfield being as low as 29·08 ins.

At 8 p.m. the area of the storm extended from Central Minnesota to the Gulf of Mexico, and from Nebraska to Pennsylvania, with snow in Minnesota, Nebraska, Iowa, Wisconsin and Northern Ohio, while heavy rain was falling in Kansas, Illinois, Indiana, Ohio and Pennsylvania, and rapidly extending in advance of the storm centre.

While the storm was moving eastward every condition appeared favourable for the most violent local storms. The colder and very high North-west winds were setting in on the rear of the storm, causing the temperature in Kansas and Missouri to drop to within two or three degrees of the freezing point. At the same time the warmer air from the south was being drawn north to fill the vacuum occasioned by the storm centre, and the temperature as far north as Louisville standing at 66° and a little to the south at 70°, made a difference of nearly 40° in temperature in the space of only a few miles. It was the intermingling and clashing of these two air currents that formed the local tornadoes on the southern border of the storm centre.

The storm passed on from Illinois, crossing Indiana and Ohio, and at 8 a.m. on the 28th the centre was over Lake Erie, rain then falling in all the States south of the lakes to Georgia, and along the Atlantic as far north as Boston, and snow falling in Illinois, Michigan, Northern New York, Maine, and Canada, and high winds prevailed in all the States from the Mississippi Valley east to the Atlantic seaboard. During the night the storm passed away to the north-east over northern New York and Maine, out to the Atlantic.

It is reported that two tornado paths were developed, one in Southern Illinois, the other in Kentucky. The former passed south-east into Tennessee, while the latter spent its force north-east of Jeffersonville.

The tornadoes in Southern Illinois occurred between 3 and 5 p.m., while that at Louisville and Jeffersonville took place about 9 p.m. The path of the tornado, which passed through Metropolis, was 800 yards wide.

These tornadoes caused immense loss of life, destroyed towns, blew trains off the track, and left wreck and ruin in their path.

Of course the telegraphic information that has appeared in the English newspapers is very scanty, but from this we learn that in

| | | | | |
|---|---|---|---|---|
| Jackson County, Illinois, | | 16 | persons were | killed. |
| Grand Tower | ,, | 6 | ,, | ,, |
| Gallatin, Tennessee | ,, | 4 | ,, | ,, |
| Marion, Kentucky | ,, | 18 | ,, | ,, |
| Blackford ,, | ,, | 80 | ,, | ,, |
| Dixon ,, | ,, | 8 | ,, | ,, |

The greatest loss of life was at Louisville, Kentucky, where the tornado passed right through the town. It is reported that at least 100 persons were killed.

An observer of the cyclone cloud, living on the north side of the Ohio, thus describes it;—

"The cloud approached through the gap in the hills below Louisville, through which the Ohio river flows. It was in the shape of a balloon, constantly rotating, and with an attenuated tail towards the earth. It emitted a constant fusillade of thunder and lightning, and seemed composed of a snakelike whirling mass of electric currents, whose light was sometimes suddenly extinguished for brief seconds, leaving a terrible darkness. The cloud made a fearful roar. It came through the gorge into the city, moved with great rapidity and with an awful rumbling sound, leaped across the river, changing the waters into white foam, and disappeared through Jeffersonville."

A lady at Rogana says:—

"Hearing the roar of the wind I stepped to the door to look out. Just as I opened the door I saw such a sight as I hope never to see again. Right in front of the house was a low-hanging terrible black cloud. It seemed to have more the appearance of a bird's nest, hung from the large or open end and swinging violently about. I saw what seemed to be trees or parts of houses, and even animals, whirled about in it. I was for a moment very much frightened, and screamed for some one to come. I cannot yet remember that it seemed to come nearer, but the next thing I knew we were without a house, and the rain was pouring down on us."

Sergeant J. P. Finley in his "Report on the character of Six Hundred Tornadoes" (*Professional Papers of the Signal Service*, No. VII.) gives some interesting information as to the frequency, distribution and characteristics of tornadoes. From this we learn that the States in which the greatest number of tornadoes occurred are Kansas, Illinois, and Missouri. Tornadoes occur most frequently in the afternoon between four and six o'clock, June being the month with the greatest frequency. The average width of the path of destruction is 1085 feet, the velocity 80 miles an hour, and the length of the track of the tornado about 28 miles.

The tornado cloud usually looks like a huge funnel, bounding along like a ball, rising and falling, or darting from one side of its path to the other. The velocity of the wind within the cloud vortex has been variously estimated at from 70 to 800 miles an hour, the average being 392 miles. This great inrush of air draws everything into the vortex, and produces a terrible deafening roar.

At the Royal Meteorological Society's Exhibition last month there was shown a very fine collection of photographs of damage caused by several tornadoes in America (p. 184). These very clearly and strikingly illustrated the destructive character of the tornadoes. The most remarkable photograph was that showing pieces of straw driven end-on into the bark of trees.

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## The Pole Star Recorder.

(Communicated to the International Meteorological Congress at Paris in September 1889, by A. L. Rotch, B.Sc., F.R.Met.Soc.)

An instrument invented by Prof. Pickering, director of the Astronomical Observatory of Harvard College, has been employed at the Blue Hill Meteorological Observatory since January 1889, to register the cloudiness during the night. This consists of a telescopic objective attached to a photographic camera and directed to the Pole Star. The camera is provided with very sensitive plates, which are inserted in the evening, and a shutter worked by an alarm clock is closed before dawn. If the sky was clear during the night, the plate after development shows a circle traced by the revolution of the star around the North Pole, but if clouds passed the trail is broken.

By means of a datum point which is worked on the plate when it is exposed, and a circle divided into hours, the time during which the Pole Star shows brightly is obtained for each hour, and the complement gives the cloudiness as in the Sunshine Recorder.

Although the part of the sky photographed is only the region of the pole, yet the mean values derived from this instrument agree fairly well with eye observations embracing the whole sky, as the following table shows.

The mean cloudiness is expressed in hundredths, and the figures in parentheses give the mean of the cloudiness observed directly at the commencement and end of each hour, except for 6 a.m.

CLOUDINESS AT NIGHT AT BLUE HILL OBSERVATORY, MASS. U.S.

| 1889. | Hours ending | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P.M. | | | | | | A.M. | | | | | | |
| | 7. | 8. | 9. | 10. | 11. | 12. | 1. | 2. | 3. | 4. | 5. | 6. | 7. |
| January | 38 | 45 | 43 | 45 | 45 | 42 | 45 | 47 | 44 | 47 | 51 | 54 | .. |
| | (42) | (43) | (43) | (44) | (47) | .. | .. | .. | .. | .. | .. | .. | (52) |
| February | 38 | 40 | 42 | 44 | 48 | 54 | 57 | 52 | 47 | 54 | 47 | 43 | .. |
| | (41) | (40) | (42) | (45) | (46) | .. | .. | .. | .. | .. | .. | .. | (53) |
| March | .. | 64 | 61 | 56 | 56 | 56 | 57 | 53 | 55 | 59 | 61 | .. | .. |
| | .. | (61) | (59) | (57) | (56) | .. | .. | .. | .. | .. | .. | .. | (70) |
| April | .. | 53 | 50 | 49 | 46 | 47 | 61 | 66 | 64 | 58 | .. | .. | .. |
| | .. | (58) | (55) | (55) | (54) | .. | .. | .. | .. | .. | .. | .. | (64) |
| May | .. | .. | 46 | 47 | 45 | 41 | 41 | 43 | 51 | 47 | .. | .. | .. |
| | .. | .. | (56) | (53) | (52) | .. | .. | .. | .. | .. | .. | .. | (59) |
| June | .. | .. | .. | 64 | 62 | 67 | 66 | 70 | 68 | .. | .. | .. | .. |
| | .. | .. | .. | (65) | (64) | .. | .. | .. | .. | .. | .. | .. | (72) |

## DR. VAN BEBBER'S "LEHRBUCH DER METEOROLOGIE FUR STUDIERENDE."

DR. van Bebber, whose *Handbuch der ausübenden Witterungskunde* appeared a few years ago, has now brought out a Handbook of Meteorology,[1] which is intended to take a middle position between Sprung' *Lehrbuch*—which is too mathematical for ordinary use,—and Mohn's *Grundzüge*, which deals with the subject from the point of view of weather.

The present volume is certainly useful, and will long hold its own as the standard work of reference, for Schmid's book is now very antiquated. The author is generally very careful in giving his references, though a complaint of some neglect on this score has just appeared from Dr. von Bezold.

The last three chapters, which deal with weather, are particularly interesting. The illustrations are not always good, apparently old clichés have been used to swell the number of illustrations.

We notice several slips in spelling English names, *e.g.*, Mr. John F. Campbell, of the Sunshine recorder, appears as H. P. Campbel.

Daniell's Hygrometer is figured, and is described at p. 110 as Regnault's condensing Hygrometer!! a very great instance of carelessness.

The correction of the press has been negligently done. At p. 246 Dr. van Bebber gives the following figures on Dr. Hellmann's authority for the liability of trees to be struck by lightning:—

Beech 1, Fir 155, Oak 54.

The true figures are—

Beech 1, Fir 15, Oak 54.

## ON THE NOCTURNAL TEMPERATURE OF THE AIR AT DIFFERENT HEIGHTS.

HERR Julius Juhlin has recently communicated a paper on this subject[2] to the Royal Society of Science, Upsala, of which the following is a summary:—

1. The depression of the temperature caused by radiation from exposed thermometers is almost constant at different heights, starting from ½ metre above the surface of the snow.

2. On fine nights in winter the temperature increases with height. The phenomenon commences two or three hours before sunset, and continues till an hour or two after sunrise.

[1] Dr. W. J. van Bebber. *Lehrbuch der Meteorologie fur Studierende und zum Gebrauche in der Praxis.* Stuttgart, Ferdinand Enke. 8vo. 391 pp. With 120 cuts and 5 plates.

[2] "Sur la Température nocturne de l'air à différentes hauteurs." Par Julius Juhlin. *Nova Acta Reg. Soc. Sc. Ser. III.*

3. The increase of temperature with height is greater in winter than at other seasons.

4. The increase is a linear function of the temperature. The lower the temperature the greater the increase.

5. On overcast and misty nights in winter the temperatures at different heights are nearly equal.

6. The variation of temperature follows the variation of the amount of cloud very exactly.

7. A thin veil of high clouds interferes very slightly with the increase of temperature with height.

8. In winter the surface of the snow is colder than the ambient air.

9. The fact that snowy winters are characterised by severe and protracted frost is well explained by the physical properties of snow.

10. The temperature on hills and at great heights is higher than on plains during winter nights.

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# RECENT PUBLICATIONS.

AMERICAN METEOROLOGICAL JOURNAL. A Monthly Review of Meteorology and Medical Climatology. April-June 1890. 8vo.

The principal original articles are:—Trombes and Tornadoes, by H. Faye (27 pp.). This is a continuation of the translation of Mons. Faye's papers.—Viñes' Laws of Recurvature, by A. H. Dutton (8 pp.). This is an examination of the truth of the laws laid down by Viñes for the recurvature of West India hurricanes. These are thus interpreted by Mr. E. Hayden:—"In June (and October) the vertex of the parabola is in about lat. 20° to 23° N; in July (and September) 27° to 29°; and in August 30° to 32°." Mr. Dutton has examined all the hurricanes in these months in 1887-89, and finds that out of 24 instances only 4 recurved within the prescribed limits, and 18 did not recurve at all. This gives only 14 per cent. of the storms recurving. If only the storms which were undoubted hurricanes were taken, there would be only 31 per cent. of success for the law. Taking 82 hurricanes in these months in previous years, only 25 per cent. obeyed the law. Mr. Dutton, therefore, concludes against the law.—The International Hydrological and Climatological Congress at Paris, by A. L. Rotch (4 pp.). This is an account of the proceedings of the Congress which was held at Paris in October 1889.—State Tornado Charts, by Lieut. J. P. Finley (17 pp.). The States dealt with are Pennsylvania, New Jersey, Delaware, Maryland, Virginia and West Virginia.—Concerning Thermometers, by Prof. W. A. Rogers (9 pp.).—Weyher's Experiments on Whirlwinds, Waterspouts, Storms and revolving Spheres, by Prof. E. Mascart (12 pp.).—Laws of the distribution of Cloudiness over the surface of the globe, by L. Teisserenc de Bort (11 pp.). The author shows that in all months there is a well-marked tendency for the cloudiness to arrange itself in zones parallel to the equator. When the distribution of cloudiness is separated from the perturbations which complicate it, in order to regard only the general phenomena, there are seen to exist (*a*) a maximum of cloud at the equator, changing its position slightly according to the sun's declination; (*b*) a band of little cloud between 15° to 35° of north and south latitude; (*c*) a zone of clouded sky from 35° to 50°, while higher, judging by what occurs in the northern hemisphere, the sky becomes clearer towards the poles. The conditions which cause perturbations in this general distribution are the following:—1. Other things being equal, the cloudiness is much less over the continents than over the oceans; 2. Every elevated coast exposed to a prevailing sea wind gives rise to a maximum of relative cloudiness; 3. Every region covered by the sea, where a continental wind prevails, has a relative minimum of cloudiness; 4. A wind which passes from a warm region to a colder one causes an increase of cloudiness.—New England Meteorological Society (15 pp.). This is a full account of the proceedings at the Meeting of the Society on April 15th. The chief subject of discussion was "climatic changes," which were considered under two heads, viz. Secular Changes, and Supposed recent Changes in Climate.

K. SVENSKA VET.-AKAD. HANDLINGAR. Band 15, Afd. 1, No. 14. Stockholm, 1890. 8vo.

Contains:—Ueber die Einwirkung der ablenkenden Kraft der Erdrotation auf die Luftbewegung, von Nils Ekholm (51 pp.). The author summarises his conclusions as follows:—1. The vertical component of the deviation force of the earth's rotation exerts a great influence (*a*) in respect of the origin and maintenance of the Trade Winds and Monsoons; (*b*) in respect of the general air currents of the Temperate Zones, especially of the Southern, where the circumstances are more typical and simpler, as well as in the great Antarctic depression; and (*c*) in respect to the dissymetry of the different winds in cyclones both in the Torrid Zone and in high latitudes, and both for the lower and the upper currents of air. 2. That the horizontal component of deviation produced by the vertical component of velocity of the air cannot be devoid of importance for the upper currents, especially in tropical cyclones, although no accurate observations are available to test the theory. He concludes by expressing the hope that accurate observations of upper currents may ultimately furnish facts to support his theory.

METEOROLOGISCHE ZEITSCHRIFT. Redigirt von Dr. J. HANN und Dr. W. KÖPPEN. April-June 1890. 4to.

The principal articles are: Der Sturm vom 11 bis 14 März 1888 an der atlantischen Küste der Vereinigten Staaten: von Dr. W. J. van Bebber (6 pp.). This is an account of the great Blizzard which Mr. E. Hayden has described.—Ueber die Beziehungen zwischen dem Wasserstand eines Stromes, der Wasserführung desselben und der Niederschlagshöhe im zugehörigen Stromgebiet: von Dr. W. Ule (6 pp.). This is a paper of considerable interest to engineers. The author shows by very careful measurements on the Saale how very unsafe it is to base any calculations as to the general rainfall from the condition of the river, either as to level or quantity of water. The following figures prove this; they are all percentages, and are differences from the 15 year mean:—

| | 1872-76. | 1876-81. | 1882-86. |
|---|---|---|---|
| River-level ... | —10·6 | + 9·8 | +1·4 |
| Rainfall ... | — 5·2 | + 0·2 | +5·1 |
| Quantity of water | —14·8 | +12·8 | +1·9 |

There is no relation between these figures.—Ueber die Theorien des allgemeinen Windsystems der Erde, mit besonderer Rücksicht auf den Antipassat: von A. Sprung (17 pp.). This is a summary and comparison of the theories of Werner von Siemens and of Ferrel. He states the following result of his discussion: If a body of the mass $m = 1$, which rotates on the earth's surface in latitude $\phi_0$ with a relative velocity without friction from west to east of $v$, is to be transferred to another latitude $\phi$, an external force must be applied in a meridional direction, which when the displacement is uniform is exactly equal to the gain of the body in *vis viva* of the relative velocity of rotation. This increase in *vis viva* follows a regular law. In the special case that the body is originally in a condition of relative rest, this expression takes a simpler form. The gain in *vis viva* of the relative velocity of rotation is always positive, so that whether the displacement is toward lower or higher latitudes, an external force must always be applied.—Die Dauer der Schneedecke im Bereiche des sächischen Erzgebirges: von Dr. O. Birkner (5 pp.). This is a discussion of six years' observations of the duration of snow in the Erzgebirge. The increase in duration does not correspond with increase in elevation.—Resultate der meteorologischen Beobachtungen an der finnländischen internationalen Polar station: von J. Hann (16 pp.). There are three notices of Sodankylar in Lapland, of Nova Zembla, and of Ssagastyr, at the mouth of the Lena. At the last-named station the observations were continued for 22 months. Dr. Bunge tells of an extraordinary rodent (the Tarbagan Arctomys) which is dormant for eight or nine months while the snow is on the ground, and consequently only lives actively for three months in the year. He also says that he himself suffered much more from cold in summer than in winter, when the temperature ranged about —50°C. He occasionally stood in his shirt in the open air at such a temperature without harm.

**Results of Rain, River, and Evaporation Observations made in New South Wales during 1888: H. C. Russell, B.A., F.R.S., Government Astronomer. 8vo. 1889. 144 pp. and 2 plates.**

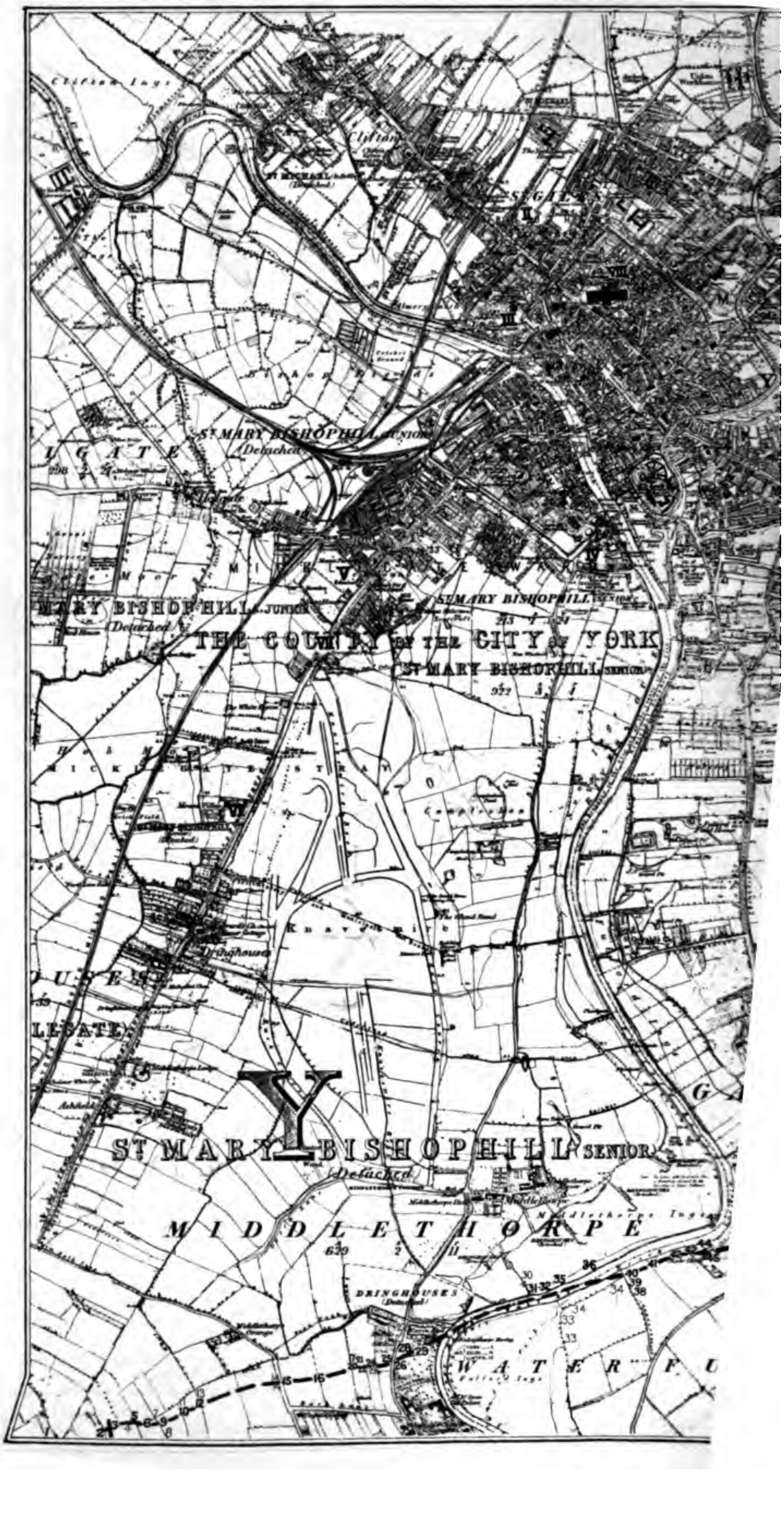
The year 1888 stands out conspicuously as the driest year upon record, and in striking contrast with 1887, the wettest on record. The remarks from nearly all parts of the Colony present the intensity of the drought, the only mitigation of which was that it followed immediately upon an abundant rainfall, which left the country charged with water in soil, rivers, and springs, as well as the abundant grasses which had resulted from such a season. In some places it would appear that 1865 was, if anything, worse than 1888, but the bulk of the evidence goes to show that, generally over the colony, 1888 was the driest year since the settlement of the country. And there are some facts which go a long way towards proving that there has been no such drought before for fifty years. In the neighbourhood of Narandera the total fall for the year was only 8 inches, not one-half of the average, and no rain sufficiently heavy to run on the surface fell between the end of October 1887 and the end of 1888. So intense was the drought there, that the native trees on the hills were all in a dying state, and over large areas absolutely dead, a state of matters which it was evident from the age of the trees killed could not have been experienced within the last fifty years. Generally, the remarks show that it was the driest year on record, experience in some cases extending over thirty years, and in other cases to the first settlement of the country about the Bland. When the break came in the weather in December, terrific thunder and hail storms occurred in many places, especially in the Northern districts, and the dry grass was in many places set on fire by the intensity of the lightning flashes. Taking the average rainfall of the whole colony from all stations for 1888, it is only 13·40 ins., which is the smallest on record. The effect of the drought is seen very clearly in the river records. With all the drainage from 1887, and some rain in February, the Darling fell rapidly, and by the middle of April was at Bourke down to summer level, and there it has remained ever since. While the Murray, at Albury, has not risen more than 1 ft. or 2 ft. by any rainfall during the year until June, and then only rose 5 ft.; there was a slight rise in July, another in the beginning of September, and the highest of the year (10 ft.) at the end of that month. Since then it has gone gradually down. Swamps in the Port Stephens district that have never been dry before, within the knowledge of black or white men, dried up during the year; and the Narran Lake at the end of the year was a dry plain, with wild fowl lying dead all about it.

**Symons's Monthly Meteorological Magazine. April-June 1890. Vol. XXV. Nos. 291-293. 8vo.**

The principal articles are:—Bibliography of Meteorology (8 pp.).—Pre-instrumental Meteorology (8 pp.).—Areas of Rarefaction or Depressions; by Dr. H. Muirhead, Rev. G. T. Ryves, and Rev. W. C. Ley (5 pp.).—Great rainfall at Hong Kong, May 29th and 30th, 1889 (5 pp.).—Anemometers, and damage by gales of wind; by W. J. Black (2 pp.).—Cycles of drought and good seasons in Africa; by D. E. Hutchins (2 pp.).—The Great Devonshire rains of May 25th (6 pp.).—Ozone and wind (2 pp.).

**The Diocese of Mackenzie River. By the Right Reverend W. C. Bompas, D.D.**

Within the space of 108 pages small octavo Bishop Bompas writes a succinct account of his diocese, the largest and least populous in Christendom. A central portion of Arctic America, it is probably for ever doomed to sterility by the severity of its climate. Upon its description, inhabitants, languages, fauna and flora, arctic life, meteorology, dress and habits, resources and prospects, interesting information is given in simple and elegant style. It is one of the few books on the Arctic Regions that is at once popular, readable, accurate, and without exaggeration. The chapters on arctic life and meteorology, in which it was so easy to make mistakes, are surprisingly free from any palpable errors, and, as bringing forward all the practical interest of the subject, are exceedingly well done.



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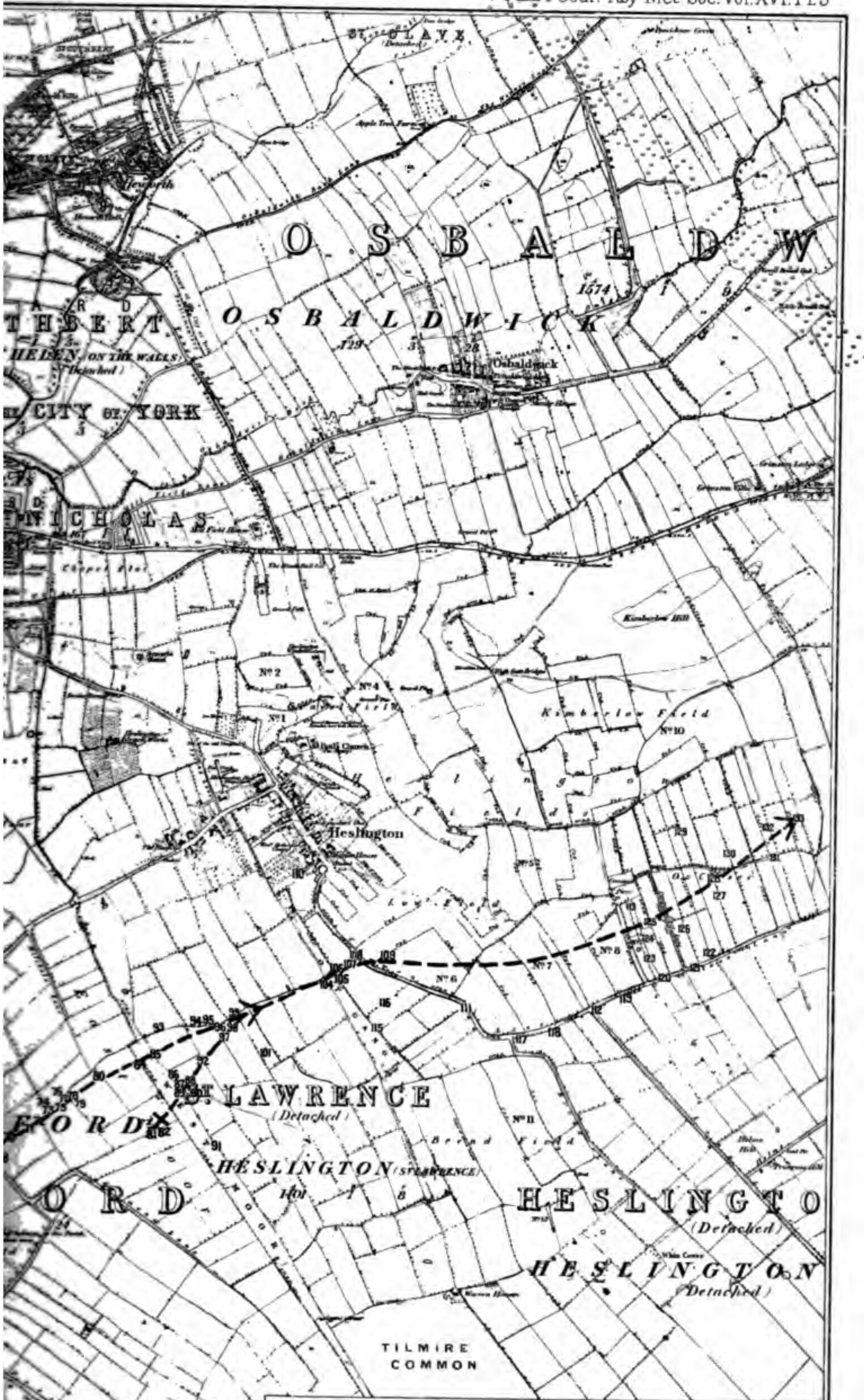

// QUARTERLY JOURNAL

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# RAINFALL OF THE GLOBE.

## COMPARATIVE CHRONOLOGICAL ACCOUNT OF SOME OF THE PRINCIPAL RECORDS.

By WILLIAM B. TRIPP, M.Inst.C.E., F.R.Met.Soc.

[Received March 31st.—Read May 21st, 1890.]

1. *Introduction.*—The Rainfall Stations contained in the Table given herewith were selected by the author on account of their suitability, as it appeared to him, to illustrate various phenomena connected with the subject of this paper; the title of which was chosen, more to show the author's aims, than to assume their successful accomplishment.

The author has endeavoured to deal principally with records coming down as nearly as possible to about the same period, and distributed as widely and evenly as possible over the earth's surface.

Such records are, as at present published, scattered throughout a numbbr of detached reports and returns of various kinds, and the search for them has involved much expenditure of time and labour.[1]

[1] The author begs to offer his acknowledgments to those who have kindly assisted him in his search, particularly to Mr. R. H. Scott, F.R.S., of the Meteorological Office, and Mr. W. Marriott of the Royal Meteorological Society, and their respective assistants, for information and aid given him with reference to the publications contained in the libraries under their charge, and also Mr. W. Ellis, F.R.A.S., of the Royal Observatory, Greenwich, and to the directors of various foreign Observatories who have kindly sent him MS. records in answer to his applications.

The author presumes that he will be expressing the opinion of all when he refers to one forcibly impressed on himself during this inquiry, as to the desirability of having rainfall records collected and tabulated in an easily accessible form, but he fears that it may be some little time before this result is accomplished.

The author considers the present attempt only in the light of a preliminary inquiry, entered upon to obtain information for himself while engaged in Hydraulic Engineering pursuits, and in the hope of throwing some light on, and in some measure assisting in, a difficult inquiry. He does not claim that this list is in any way final or complete, but the selection appeared to him to be the best that could be readily obtained, and he would be much obliged to anyone who would give him information with a view of making it more complete.

2. *General arrangement of records*.—The Northern and Southern Hemispheres, as usually shown on maps of the world published in this country, have been divided into Quadrants, as follows:—

| Northern Hemisphere. | Principal Divisions. |
|---|---|
| 1. NW. Quadrant of Eastern Hemisphere | Europe and Algeria. |
| 2. NE. ,, ,, ,, | Asia. |
| 3. NE. ,, Western ,, | California. |
| 4. NW. ,, ,, ,, | U. S. America and Barbadoes. |
| Southern Hemisphere. | |
| 5. SW. Quadrant of Eastern Hemisphere | Cape of Good Hope, Mauritius, &c. |
| 6. SE. ,, ,, ,, | Australia and Batavia. |
| 7. SE. ,, Western ,, | New Zealand. |
| 8. SW. ,, ,, ,, | Buenos Ayres, &c. |

3. *Parts unrepresented*.—It is evidently, however, quite impracticable to obtain suitable records of rainfall from all parts of the globe, and many parts,—such as large tracts in North America, nearly the whole of the interior of South America and Africa, the North and West of Australia, large tracts of Asia and the surface of the Ocean, and most of the Islands studding its surface,—possess either very short records or none at all.

The Western and Southern parts of Europe of course present a series of records which, for length of period of observation and completeness, cannot be approached by those of any other parts of the World, but one region in respect of which difficulty has been found in obtaining continuous records is the Southern part of France from about 1871 to 1875.

A similar series of blanks appears in most of the Indian records from about 1854 to 1860. Presumably in both these cases the deficiency is due to the disturbed state of those countries, owing to the struggles happening about those periods.

4. *Interpolation*.—Unfortunately some of the best individual records are not continuous, and in many cases the present tabular records are analysed without filling in the blanks, when these are not very serious, but where it has

been found desirable the author has filled them in from the nearest and most suitable stations he could discover; the values being altered where necessary in the ratio of the means of the years common to the records.

In some cases one record is from the earlier portion and another the later portion, the values being adjusted as above described.

Records so combined must be considered joint records, the figures so filled in, while they doubtless frequently approximately represent the true fall at both stations, being necessarily true only for the station from the records of which they were taken.

5. *Reliability of the records.*—The author has taken these generally on the authority of those by whom they were published, but correcting as far as possible clerical errors, and making the means afresh.

He has, when practicable, compared the simultaneous records of great rainfalls and droughts, and, from considerations arising out of such investigations, has formed the opinion that while the absolute amount of registered rainfall at different periods may have been affected by modes of collecting rainfall differing from the improved methods at present in use, yet that the published records indicate generally the comparative fluctuations in the relative amounts of the fall from time to time.

The records, however, present several startling features. In the record of Paris it will be found that of the 35 consecutive years, 1714-48, 2 only, 1739 and 1740, were above the mean of the 171 years recorded.

In corroboration of the truth of this we find historians recording the greatest distress as existing among the French peasantry about the middle of the century, and although this is generally attributed to political causes, yet it appears to the author possible, at any rate, that this terrible drought, which must have had such an effect on agriculture, although the records of it may have been exaggerated, may have had some effect in causing the state of things which then existed, and which was ultimately instrumental in hastening on the catastrophe of the French Revolution itself.

It is not easy to get records old enough to compare with this period, but we find that at Padua 1735-41 were much below the mean of the 161 years recorded.

The English values also, as has been pointed out by Mr. Symons, show that a drought prevailed in England at this time, the 5 years 1729-33, and the 23 years 1738-62, all but two, 1751 and 1756, were below the mean, the 13 years 1738-50 having been the driest period, and were all below the mean.

Other old records show similar droughts about the same time, while others do not do so.[1]

Again, in more modern times the records of Barnaul show a period from 1852-74, 23 years, during which time only 3 years, 1856, 1868 and 1872, were

[1] It may be worth while to mention that there appears to be a tradition of a great and fatal drought both to trees and men having occurred in South Australia about the middle of last century. See H. C. Russell, "Meteorological Periodicity," *Journal of the Royal Society, N. S. Wales*, 1876; also "Egeson's Weather System," Sydney, 1889.

## TABLE GIVING SOME CHIEF PARTICULARS OF RECORDS.

### NORTHERN HEMISPHERE.

| No. | Name of Station. | Period. | | | Wettest Years. | | Means. | Driest Years. | | Percentages. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First and Last Complete Years. | | Total No. of Complete Years. | Date. | Inches. | Inches. | Date. | Inches. | Mean = 100. Wettest. | Mean = 100. Driest. | Wettest = 100 Driest. |
| | N.W. Quadrant of Eastern Hemisphere.—Europe and Algeria. | | | | | | | | | | | |
| 1 | Edinburgh .......... | 1824 | 1887 | 64 | 1872 | 39·0 | 26·0 | 1887 | 13·7 | 150 | 53 | 35 |
| 2 | Kendal .............. | 1788 | 1887 | 100 | 1792 | 83·6 | 52·4 | 1887 | 32·4 | 159 | 61 | 39 |
| | | | | | | | | | | L | | $H_4$ |
| 3 | Ratios 100 = 30″ ...... | 1726 | 1887 | 162 | 1852 | 40·8 | 30·0 | 1741 | 17·4 | 136 | 58 | 43 |
| 4 | Exeter[1] ............. | 1815 | 1887 | 73 | 1872 | 46·0 | 30·2 | 1854 | 18·1 | 152 | 60 | 39 |
| | | | | | | | | | | | H | H |
| 5 | London[1] ............. | 1813 | 1887 | 75 | 1852 | 35·3 | 24·6 | 1858 | 17·3 | 144 | 70 | 49 |
| | | | | | | | | | | | | $H_4$ |
| 6 | Brussels ............ | 1823 | 1887 | 55 | 1878 | 41·2 | 28·6 | 1864 | 17·7 | 144 | 62 | 43 |
| 7 | Paris ................ | 1689 | 1885 | 171 | 1804 | 27·7 | 19·2 | 1733 | 8·3 | 144 | 43 | 30 |
| 8 | Geneva ............... | 1826 | 1885 | 60 | 1841 | 49·5 | 32·3 | 1832 | 20·7 | 153 | 64 | 42 |
| | | | | | | | | | | $H_5$ | | |
| 9 | La Rochelle .......... | 1810 | 1885 | 72 | 1866 | 50·0 | 25·6 | 1869 | 14·2 | 195 | 55 | 28 |
| | | | | | | | | | | $L_3$ | | |
| 10 | Toulouse ............ | 1805 | 1885 | 79 | 1879 | 36·3 | 25·4 | 1822 | 15·3 | 143 | 60 | 42 |
| 11 | Lisbon ............... | 1784 | 1887 | 54 | 1855 | 51·0 | 28·3 | 1837 | 13·5 | 180 | 48 | 26 |
| | | | | | | | | | $D_8$ | $H_6$ | | |
| 12 | Oran ................. | 1841 | 1886 | 46 | 1870 | 37·1 | 19·1 | 1885 | 8·9 | 194 | 47 | 24 |
| 13 | Algiers .............. | 1838 | 1886 | 49 | 1847 | 51·4 | 31·1 | 1866 | 19·3 | 165 | 62 | 38 |
| 14 | Constantine .......... | 1838 | 1886 | 49 | 1854 | 42·5 | 24·5 | 1878 | 10·7 | 173 | 44 | 25 |
| 15 | Palermo ............ | 1806 | 1887 | 82 | 1883 | 37·6 | 23·8 | 1866 | 10·8 | 158 | 45 | 29 |
| 16 | Lico rotondo.......... | 1829 | 1886 | 58 | 1858 | 67·0 | 36·3 | 1882 | 17·6 | 185 | 49 | 26 |
| 17 | Naples .............. | 1821 | 1887 | 65 | 1868 | 50·4 | 32·6 | 1880 | 16·0 | 154 | 49 | 32 |
| 18 | Rome ................ | 1825 | 1887 | 63 | 1875 | 48·5 | 30·4 | 1834 | 12·6 | 160 | 41 | 26 |
| | | | | | | | | | | $H_4$ | | |
| 19 | Marseilles ............ | 1823 | 1886 | 64 | 1872 | 43·0 | 20·7 | 1837 | 10·6 | 208 | 51 | 24 |
| | | | | | | $W_4$ | | | | $H_3$ | | |
| 20 | Genoa ............... | 1833 | 1887 | 55 | 1872 | 108·4 | 51·4 | 1861 | 28·2 | 211 | 55 | 26 |
| | | | | | | W | $W_5$ | | | $H_2$ | | $L_2$ |
| 21 | St. Bernard Hospice .. | 1818 | 1885 | 68 | 1839 | 160·9 | 55·7 | 1857 | 22·9 | 289 | 41 | 14 |
| 22 | Milan ............... | 1764 | 1887 | 124 | 1814 | 62·0 | 39·4 | 1871 | 25·2 | 157 | 64 | 41 |
| 23 | Padua .............. | 1725 | 1887 | 163 | 1772 | 61·5 | 33·8 | 1822 | 17·8 | 182 | 53 | 29 |
| 24 | Kremsmünster ...... | 1821 | 1887 | 67 | 1867 | 56·3 | 38·5 | 1822 | 22·8 | 146 | 59 | 41 |
| | | | | | | | | | | $H_4$ | | |
| 25 | Warsaw .............. | 1813 | 1886 | 69 | 1833 | 46·5 | 22·4 | 1822 | 14·6 | 208 | 65 | 31 |

[1] Two records combined.

N.B.—In the above Table H $H_2$ &c. mean the Highest respectively in order.
$L_1$ $L_2$ ,, ,, Lowest ,, ,, ,,
$W_1$ $W_2$ ,, ,, Wettest ,, ,, ,,
$D_1$ $D_2$ ,, ,, Driest ,, ,, ,,
All in the order given by the small figures in the Northern and Southern Hemispheres respectively.

NORTHERN HEMISPHERE.

| No. | Name of Station. | Period. First and Last Complete Years. | | Period. Total No. of Complete Years. | Wettest Years. Date. | Wettest Years. Inches. | Means. Inches. | Driest Years. Date. | Driest Years. Inches. | Percentage. Mean = 100. Wettest. | Percentage. Mean = 100. Driest. | Percentage. Wettest = 100 Driest. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N.W. Quadrant of Eastern Hemisphere.—Europe and Algeria.** *Continued.* | | | | | | | | | | | |
| 26 | Upsala .............. | 1836 | 1887 | 52 | 1866 | 32·0 | 21·4 | 1875 | 12·2 | 149 | 57 | 38 |
| 27 | St. Petersburg ......... | 1836 | 1886 | 51 | 1864 | 29·3 | 19·1 | 1853 | 12·1 | 153 | 63 | 41 |
| 28 | Lugan .............. | 1838 | 1886 | 48 | 1842 | 24·4 | 14·8 | 1863 | $D_7$ 8·8 | 166 | 60 | 36 |
| 29 | Tiflis ................ | 1845 | 1886 | 41 | 1850 | 30·7 | 19·3 | 1856 | 11·3 | 159 | 58 | 44 |
| | **N.E. Quadrant of Eastern Hemisphere.—Asia.** | | | | | | | | | | | |
| 30 | Katherinenberg ...... | 1836 | 1886 | 51 | 1846 | 24·4 | $D_3$ 14·0 | 1857 | $D_4$ 6·9 | 174 | 50 | 28 |
| 31 | Bogoslowsk .......... | 1838 | 1886 | 48 | 1846 | 28·4 | 16·2 | 1869 | $D_8$ 5·4 | 175 | $L_3$ 33 | $L_8$ 19 |
| 32 | Barnaul ........... | 1838 | 1886 | 49 | 1839 | 17·7 | $D_3$ 10·6 | 1864 | $D_2$ 4·2 | 167 | 40 | 24 |
| 33 | Nertschinsk .......... | 1839 | 1884 | 42 | 1844 | 25·9 | 16·1 | 1860 | $D_5$ 7·2 | 160 | 44 | 28 |
| 34 | Pekin ................ | 1841 | 1883 | 32 | 1871 | 41·9 | 25·4 | 1869 | $D_9$ 9·5 | 165 | $L_4$ 38 | 23 |
| 35 | Calcutta.............. | 1829 | 1886 | 58 | 1871 | 93·3 | $W_2$ 65·4 | 1879 | 43·5 | $L_3$ 143 | 66 | $H_2$ 47 |
| 36 | Jubbulpore .......... | 1845 | 1886 | 42 | 1884 | 94·8 | 53·8 | 1868 | 28·8 | 176 | 54 | 30 |
| 37 | Almora ............. | 1845 | 1886 | 41 | 1879 | 61·7 | 39·0 | 1860 | 21·9 | 158 | 56 | 36 |
| 38 | Agra ................ | 1845 | 1886 | 38 | 1873 | 46·5 | 26·6 | 1877 | $D_{10}$ 10·0 | 175 | $L_4$ 38 | $L_5$ 22 |
| 39 | Bombay.............. | 1817 | 1886 | 70 | 1828 | $W_2$ 122·0 | W 74·0 | 1824 | 33·9 | 165 | 46 | 28 |
| 40 | Shimoga ............ | 1837 | 1886 | 50 | 1882 | 57·9 | 30·9 | 1843 | 15·3 | 187 | 50 | 26 |
| 41 | Bangalore ............ | 1835 | 1886 | 51 | 1874 | 56·6 | 35·7 | 1838 | 16·0 | 159 | 45 | 28 |
| 42 | Madras.. ............ | 1813 | 1886 | 74 | 1827 | 88·4 | 49·3 | 1832 | 18·4 | 179 | $L_8$ 37 | $L_4$ 21 |
| | **N.E. Quadrant of Western Hemisphere.—California.** | | | | | | | | | | | |
| 43 | Sacramento .......... | 1850 | 1887 | 38 | 1884 | 34·9 | 19·4 | 1877 | $D_6$ 8·4 | 180 | 43 | 24 |
| 44 | San Francisco ........ | 1850 | 1885 | 36 | 1884 | 38·8 | 23·9 | 1877 | 11·9 | 162 | 50 | 31 |
| 45 | San Diego............ | 1850 | 1885 | 36 | 1884 | 27·6 | D 9·5 | 1863 | D 3·0 | H 291 | L 32 | L 11 |
| | **N.W. Quadrant of Western Hemisphere.—United States and Barbados.** | | | | | | | | | | | |
| 46 | Barbados[1] ............ | 1843 | 1886 | 44 | 1844 | 78·5 | $W_3$ 57·8 | 1885 | 38·4 | L. 136 | 66 | H 49 |
| 47 | New Orleans, &c.[1] .... | 1836 | 1885 | 48 | 1846 | $W_8$ 110·6 | $W_4$ 57·3 | 1855 | 41·9 | $H_7$ 193 | 73 | 38 |
| 48 | Ft. Leavenworth[1] .... | 1837 | 1885 | 48 | 1858 | 59·6 | 33·9 | 1843 | 15·9 | 178 | 48 | 27 |
| 49 | Cincinnati............ | 1835 | 1885 | 48 | 1847 | 65·2 | 43·7 | 1856 | 25·5 | 149 | 58 | 39 |

[1] Combined Record.

NORTHERN HEMISPHERE.

| No. | Name of Station. | Period. First and Last Complete Years. | | Total No. of Complete Years. | Wettest Years. Date. | Wettest Years. Inches. | Means. Inches. | Driest Years. Date. | Driest Years. Inches. | Percentage. Mean = 100. Wettest. | Percentage. Mean = 100. Driest. | Percentage. Wettest = 100 Driest. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **N.W. Quadrant of Western Hemisphere.—United States and Barbados.** *Continued.* | | | | | | | | | | | |
| 50 | Rochester .. .. .. | 1831 | 1885 | 53 | 1873 | 49·9 | 34·0 | 1834 | 22·9 | 147 | 67 | $H_3$ 46 |
| 51 | Boston[1] .............. | 1818 | 1885 | 68 | 1863 | 67·7 | 44·6 | 1822 | 27·2 | 152 | 61 | 40 |
| 52 | New Haven and New Bedford[1] ........ | 1804 | 1885 | 82 | 1829 | 58·1 | 42·2 | 1846 | 30·7 | $L_2$ 138 | 73 | 53 |
| | **SOUTHERN HEMISPHERE.** **S.W. Quadrant of Eastern Hemisphere.—Cape of Good Hope, Mauritius, &c.** | | | | | | | | | | | |
| 53 | Cape Town, R.O. .... | 1842 | 1888 | 47 | 1878 | 41·0 | 25·5 | 1880 | 17·7 | 161 | 69 | 43 |
| 54 | C. G. H. 31 stations[2] 30·5 = 33·9 ins. 0·5 = 14·2 ,, | 1851 | 1886 | 36 | 1872 | D 27·2 | 22·4 | 1865 | 17·0 | L 121 | H 76 | H 62 |
| 55 | Mauritius, Port Louis | 1853 | 1886 | 34 | 1873 | 75·5 | 45·9 | 1866 | 20·7 | 164 | 45 | 27 |
| | **S.E. Quadrant of Eastern Hemisphere.—Australia, Batavia, &c.** | | | | | | | | | | | |
| 56 | Adelaide ............ | 1839 | 1886 | 48 | 1851 | $D_2$ 30·9 | 21·0 | 1876 | $D_2$ 13·4 | 147 | 64 | 44 |
| 57 | Melbourne............ | 1840 | 1886 | 43 | 1849 | 44·2 | 26·9 | 1865 | 15·9 | 165 | 59 | 36 |
| 58 | Hobart .............. | 1841 | 1886 | 44 | 1863 | 40·7 | 23·4 | 1843 | $D_2$ 13·4 | 174 | 57 | 33 |
| 59 | Sydney .............. | 1841 | 1886 | 46 | 1860 | 82·8 | 49·1 | 1849 | 21·5 | 169 | 44 | $L_2$ 26 |
| 60 | Brisbane ............ | 1840 | 1886 | 36 | 1870 | 79·1 | 47·0 | 1865 | 24·1 | 168 | $L_3$ 51 | 31 |
| 61 | Batavia .............. | 1864 | 1886 | 23 | 1872 | W 94·4 | W 74·0 | 1868 | W 52·0 | 128 | $H_2$ 70 | $H_3$ 55 |
| | **S.E. Quadrant of Western Hemisphere.—New Zealand.** | | | | | | | | | | | |
| 62 | Auckland ............ | 1866 | 1886 | 21 | 1867 | 53·2 | 42·7 | 1885 | 28·1 | 125 | 66 | 53 |
| 63 | Wellington .......... | 1866 | 1886 | 21 | 1875 | 65·8 | 52·3 | 1885 | $W_2$ 36·8 | 126 | $H_2$ 70 | $H_2$ 56 |
| 64 | Dunedin ............ | 1866 | 1886 | 21 | 1886 | 52·6 | 35·5 | 1871 | 21·2 | 148 | 60 | 40 |
| | **S.W. Quadrant of Western Hemisphere.—Buenos Ayres, &c.** | | | | | | | | | | | |
| 65 | Buenos Ayres ........ | 1861 | 1888 | 28 | 1869 | 46·1 | 35·2 | 1861 | 23·0 | 131 | 65 | 50 |
| 66 | Estancia San Juan .... | 1867 | 1887 | 21 | 1883 | 58·8 | 39·5 | 1867 | 21·0 | 149 | 53 | 36 |
| 67 | Cape San Antonio .... | 1858 | 1884 | 27 | 1860 | 43·4 | 32·3 | 1861 | 20·0 | 134 | 62 | 46 |
| 68 | Bahia Blanca ........ | 1860 | 1882 | 23 | 1876 | 36·0 | 19·2 | 1861 | 8·2 | H 188 | L 43 | L 23 |

[1] Combined Record.

[2] Proportional Nos. Table III. *Quart. Jour. Roy. Met. Soc.* Vol. XIV. converted from averages of 31 stations, Table I.

above the mean 1846-85. A drought extending over a considerable portion of these years is seen at the 5 stations given in Siberia and China, and also at many of the European stations there appears a tendency in the same direction.

It may, however, be remarked that over portions of the same period there was an excess in parts of the United States; the number of years above the mean of the same period at Boston was 18, and at Rochester, U.S.A., 15; the wettest years at each of these stations having occurred during the period which was so dry in Central Asia.

At the St. Bernard, 1831-49 were chiefly characterised by an excess, while at Lisbon 1836-51 there was chiefly a deficiency of rainfall.

It may be here stated that references to the mean are merely intended to indicate that the period in question had a tendency to an excess or deficiency of precipitation without any reference to the true value of that mean. It may, however, be remarked that some of the facts which have come under the author's notice would tend to prevent him from placing too much confidence in taking as a true mean at different stations exactly the same years at each, particularly for short periods. It is obvious that if there is any general sequence existing of wet and dry periods, as some assert, and if such can be found, a true mean, if such exists, should embrace a due proportion of both wet and dry years; and on the whole it appears rather likely that the truest absolute mean is that which embraces the largest number of years.

6. *Results.*—Paris has the longest record, commencing in 1689; breaks unfortunately occur, seriously diminishing the value it would otherwise possess.

Padua, beginning in 1725, and the series compiled by Mr. Symons which the author has called the "English Ratios" beginning in 1726, present facilities for comparison and combination which appear to him to be superior to those possessed by any others.

Next comes Milan, commencing in 1764.

Thus Italy, the former home of Hydraulic Engineering, has, as might be expected, a very valuable series of older records.[1]

The observations at Kendal were commenced by the celebrated Dr. Dalton in 1788, and there are observations in Europe, Asia, North America, Australia, and the Cape of Good Hope, enabling 5 quadrants to be represented, however imperfectly, for the eight lustra from 1846-1885. The remaining quadrant in the Northern Hemisphere, containing California, only begins to be represented in 1851, with the exception of Sitka, of which the record is incomplete.

[1] The author has extracted comparatively little in proportion to the opportunity afforded from such mines of information as the "*Annali dell' Ufficio Centrale de Meteorologia*" of Italy; Schott's tables, published by the Smithsonian Institution of America; Dr. Wild's magnificent series, published at St. Petersburg; the *Indian Meteorological Memoirs* of Mr. Blanford, and Raulin's collections of the rainfall in France; but he has chosen a few of those which appeared to him the most perfect and those scattered over the widest area: the tendency of such records is to collect thickly round certain old-established centres of observation.

The earliest continuous record known by the author to exist in the Southern Hemisphere is that commenced at Adelaide, in Australia, in 1839. Then comes the Cape of Good Hope in 1842, and the Province of Buenos Ayres in 1858, but he has not obtained any previous to 1866 for the quadrant containing New Zealand, consequently for the four lustra 1866-85 all the quadrants can be in some measure represented by stations possessing records.

The *Magnitude* of fall in any particular year at the stations given varies from 160·9 ins. at the St. Bernard in 1839, to 8 ins. at Sandiego in California in 1863.

The value of the means, as taken in the table, varies from 74 ins. at Bombay, for the 70 years 1817-86, to 9·5 ins. at Sandiego for the 36 years 1850-85.

The table of percentages exhibits remarkable variations. Calling the means 100, the percentages of the wettest years vary in the longer records from 291 at Sandiego, and 289 at the St. Bernard, to 121 on the averages of all stations at the Cape of Good Hope, English Ratios and Barbadoes 136, and Calcutta and Toulouse each 143.

The percentages of the driest years vary from 76 on the average of the Cape of Good Hope, 73 at New Haven and New Bedford, 70 at London, down to 32 at Sandiego.

Calling the wettest year 100, the percentages of the driest years vary as follows,—excluding those which may be considered in some degree as averages, in which extremes are apt to become modified, and also the shorter records,—from London with 49 or about $\frac{1}{2}$, down to 14 or $\frac{1}{7}$ at the St. Bernard, and 11 or $\frac{1}{9}$ at Sandiego. These figures indicate the greatest range which exists at any station which has come under the author's observation.

The greater number of those stations exhibiting a very high range appear to be seaports, such as Sandiego, Genoa, Bahia Blanca, Marseilles, La Rochelle, Oran, New Orleans, Madras, &c.

Some, however, such as the St. Bernard and Warsaw, are not seaports, but the part of the coast to which Mont St. Bernard is nearest is that lying between Genoa and Marseilles, both of which stations exhibit a very high range.

It will be noticed that while the percentages due to wettest years vary from 291 to 143, with a difference of 148, those due to driest years vary only from 70 to 32, giving a difference of only 38.

The yearly values and those of periods of varying length appear to be continually rising and falling, and the above-mentioned phenomena are also often observed in comparing differences between the yearly maxima and minima, which are constantly occurring in different years of the same record, the former being frequently much greater. This shows how violent is the change due to wet years when they occur, and appears also to account for the excess in the number of years below a mean often seen in a long record; the general rule apparently being that droughts are longer continued, while wet periods are of greater intensity.

It also appears to follow as a kind of corollary to the above, that although some of the driest years often happen close to some of the very wettest, yet

that a high range of fall generally causes a high average fall at such a time, and the converse of this appears to be generally true. And when this occurs about the same time in a number of records combined as an average, the result is marked in the same way.

It also appears to the author worthy of being brought before the Society that by analysing these successive yearly maxima and minima by what he calls a comparative system, any record, so far as he has seen, can be divided into periods of varying length, the average of which often bears much resemblance to the much searched for shorter cycle. The method is as follows:—The ordinary yearly maxima and minima are called "extremes of the first order;" and those among these culminating points, higher or lower respectively than those on either side of them, "extremes of the second order," those of the second order, higher than those next them, are "extremes of the third order," &c.

The extremes of the first order occur on an average every 8 years in the English Ratios and in the record of Padua.

Those of the second order occur as follows in some of the larger records:—

| | | |
|---|---|---|
| English Ratios, Average Interval - | Max. 9·85 years; | Min. 9·14. |
| Padua - - - - - - - | Max. 11·08 | Min. 10·84. |
| Milan - - - - - - - | Max. 10 | Min. 9·10. |
| Geneva - - - - - - - | Max. 9·14 | Min. 7·88. |
| Kendal - - - - - - - | Max. 7·78 | Min. 10·20. |
| New Haven and New Bedford - - | Max. 9·29 | Min. 9·33. |

Third order extremes occur in the English Ratios and Padua at intervals on an average of from 24 to 34·5 years; the records are not long enough to determine the higher periods with advantage. These characteristic points do not always occur in the same year at different stations, except at epochs such as 1872 in Europe, when the rainfall is proportionally similar over wide areas.

The sun-spot record as given in the *Memoirs of the R. Ast. Soc.* Vol. XLIII. gives two second order extremes of maxima with intervals of 59 and 33 years; the intervals are 35 and 46 years in the minima down to 1856.

This method is a perfectly rigid one, and can be applied to any curve of varying extremes. In the case of the rainfall curves the interval between extremes is a highly variable one.

The following is a comparison of differences between maxima and also between minima, as shown in some of the longer records:—

| Year of Record. | Maxima. | | | | | Minima. | | | | | Differences. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Highest. | Date. | Lowest. | Date. | Difference. | Highest. | Date. | Lowest. | Date. | Difference. | Max. Greatest. | Min. Greatest. |
| | Ins. | | Ins. | | Ins. | Ins. | | Ins. | | Ins. | Ins. | |
| English Ratios ..... | 40·8 | 1852 | 19·5 | 1842 | 21·3 | 32·1 | 1881 | 17·4 | 1741 | 14·7 | 6·6 | .. |
| Padua ............ | 61·5 | 1772 | 26·4 | 1821 | 35·1 | 41·8 | 1771 | 17·8 | 1822 | 24·0 | 11·1 | .. |
| Milan ............ | 62·0 | 1814 | 36·2 | 1767 | 25·8 | 45·2 | 1844 | 25·2 | 1871 | 20·0 | 5·8 | .. |
| Geneva ............ | 49·5 | 1841 | 26·7 | 1821 | 22·8 | 34·8 | 1839 | 20·7 | 1832 | 14·1 | 8·7 | .. |
| Kendal ............ | 83·6 | 1792 | 39·5 | 1856 | 44·1 | 62·4 | 1790 | 32·4 | 1887 | 30·0 | 14·1 | .. |
| New Haven & New Bedford, U.S.A. | 58·1 | 1829 | 39·2 | 1816 | 18·9 | 47·2 | 1870 | 30·7 | 1846 | 16·5 | 2·4 | .. |

Although, in consequence of these records embracing periods of different lengths, they cannot afford conclusive evidence, from a comparison of their extreme years, as to the existence of wet or dry periods, yet the author thought it would be of interest to ascertain the number of wettest and driest years in the tables falling respectively within the successive lustra. They are as follows :—

| Wettest Years. | | No. of Years. | Driest Years. | | No. of Years. |
|---|---|---|---|---|---|
| 1772-1814 | ... | 4 | 1733-41 | ... | 2 |
| 1821-25 | ... | — | 1821-25 | ... | 6 |
| 1826-30 | ... | 3 | 1826-30 | ... | — |
| 1831-35 | ... | 1 | 1831-35 | ... | 4 |
| 1836-40 | ... | 2 | 1836-40 | ... | 3 |
| 1841-45 | ... | 4 | 1841-45 | ... | 3 |
| 1846-50 | ... | 7 | 1846-50 | ... | 1 |
| 1851-55 | ... | 5 | 1851-55 | ... | 3 |
| 1856-60 | ... | 4 | 1856-60 | ... | 7 |
| 1861-65 | ... | 3 | 1861-65 | ... | 12 |
| 1866-70 | ... | 8 | 1866-70 | ... | 9 |
| 1871-75 | ... | 14 | 1871-75 | ... | 3 |
| 1876-80 | ... | 5 | 1876-80 | ... | 6 |
| 1881-85 | ... | 7 | 1881-85 | ... | 7 |
| 1886 | ... | 1 | 1887 | ... | 2 |
| Total No. of Records | ... | 68 | ... ... | ... | 68 |

The number of wettest years falling between 1866-75 = 22, and that of driest years falling between 1861 and 1870 = 21, is worthy of remark. The year 1872 has the highest number, 6, among the wettest years, then comes 1884, 4, and 1873 and 1846, 3 each. Among the driest years 1822 comes first with 5, 1861 with 4, 1864, 1865, 1866, 1869 and 1877 with 3 each.

With respect to this agreement being strongly marked over wide areas, the year 1872 is the most remarkable instance which has come under the author's observation, nearly the whole of the stations adjacent to the Western Coasts of Europe, from Upsala in Sweden to the South-west extremity of the Spanish peninsula, a range of over 2,000 miles, having been characterised in that year by a very heavy fall, which extended a considerable distance inland.

A similar state of things prevailed also in the Cape Colony in the same year, as has been elsewhere pointed out by the author.

It is somewhat curious that just a century before that a tremendous rainfall appears to have occurred. 1772 was much the wettest recorded year at Padua, and Raulin has published records from which it appears that this was also the wettest year at Marseilles. In the English Ratios the wettest 3 years of the series culminated in 1775, and from Raulin's records it appears that the state of things in the neighbourhood of Amsterdam was very similar. In 1884 the highest recorded fall took place simultaneously at each of the 8

Californian stations, extending over 500 miles of seaboard. 1846 was very wet at the 8 stations in Central Asia, and above the mean at 6 out of the 8 Indian stations. Other similar instances might be given.

7. *Diagrams and averages.*—The author thinks it may interest the Society to exhibit diagrams of some of the principal records, and also of some numerical averages of the records of the stations subdivided in the manner shown in the table, as these have been found by the author in published records, with the necessary interpolations supplied, each average consisting of complete records extending over the same periods of time respectively.

These appear to indicate that there was an average excess of rainfall at the stations given, occurring as follows:—

In the Northern Hemisphere, at the European stations in 1872 and 1838-39; Asia in 1846, 1874 and 1884; California 1884 and 1862; Sitka, in Alaska, in 1844; the United States and Barbadoes in 1878 and 1846. The highest average for the stations representing the Northern quadrant being that for 1878.

In the Southern Hemisphere, the stations of the Cape of Good Hope and Mauritius had an average excess in 1872, 1873, 1874, 1878 and other years;[1] those of Australia and Batavia in 1870 and 1872; New Zealand 1875; Buenos Ayres 1878 and 1883; Rio Janeiro, the highest 5 years average being 1881-85. (See *Met. Zeit.* June 1889, E. A. Göldi.)

Combining the Stations in the Northern and Southern Hemispheres the highest recent averages were for the years 1879, 1883 or 1878.

An average deficiency appears as follows:—

In the Northern Hemisphere, at the European stations in 1849, 1861, 1868 and 1854; at those of Asia in 1860, 1855, 1857; California in 1877 and 1863; Sitka in 1872 and 1861; U.S.A. and Barbadoes 1885 and 1854. The lowest averages being those for 1854 and 1868.

In the Southern Hemisphere the records are not so complete for the earlier years; as far as they go, the average is lowest for the Cape of Good Hope and Mauritius stations in 1866, 1865 and 1880; in Australia and Batavia in 1865, 1868, 1881 and 1854; New Zealand 1885, 1881 and 1866; Buenos Ayres 1861. The lowest general average being 1861.

Combining the stations of the Northern and Southern Hemispheres the lowest averages are for 1854 and 1861.

The regular nature of the curves between the chief maximum culminations in the longer averages of the Northern Hemisphere is worthy of remark.

Thus the more recent highest averages are contained within the 15 years from 1870-84, and the lowest in the 18 years from 1849-66. And it is somewhat remarkable that the most recent maximum rainfall culminations in Europe should occur about 1838-9 and 1872. in a very similar manner with the appearance of the more important recent maxima of sunspots of 1837

[1] Taking South Africa alone, 1872 was on the average the wettest in all parts; 1874 was the wettest in the eastern provinces and Natal; 1876 the wettest in the eastern provinces alone; and 1878 the wettest in the Cape Peninsula and the west.

and 1870, both being about 33 years apart, and that the sunspot minimum of 1856 should nearly coincide with the corresponding rainfall minimum period, the above being sunspot culminations of the second order.

A similar comparative culmination of sunspot maxima occurred in 1778, approximately about the time of the extraordinary excess of European rainfall described above.

It must be remarked that there never appears to be an absolute excess or deficiency in any year at all the stations. On the contrary, the difficulty is to find a few stations together with a similarly proportioned rainfall.

The resulting figures tend rather to indicate whether similar changes appear at standard stations in different parts than to settle the absolute quantity of rain falling on the globe in any particular year. At the same time, so far as the evidence of the stations goes, it appears that the average is higher at certain periods than at others. The author wishes, however, to guard himself against assuming that similar changes necessarily go on over the areas lying between the stations; and he wishes to refer to averages for periods within tolerably wide limits rather than to the values for particular years, and he thinks that such periods appear to display a somewhat symmetrical variation in different parts of the globe, though the characteristics of some years are more developed at certain stations than at others.

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## DISCUSSION.

Mr. HUTCHINS said that nearly all the periods of excess of rainfall quoted by Mr. Tripp corresponded with the cyclical periods of heavy rainfall in Cape Colony, the only two exceptions being 1844 and 1846. The periods of drought also coincided very closely with the South African rainfall cycles, there being but five exceptions out of a total of nineteen periods, and these five were not entire exceptions. As regards sunspots and seasons, Mr. Tripp's maximum rainfall periods would be found to correspond more closely with Dr. Wolff's cycle of 11·11 years than with sunspots as observed. This, as he had shown elsewhere, was one of the most remarkable features in the regular rainfall of Cape Town.

Dr. TRIPE drew attention to the great difference in the elevation of some of the stations. He thought that the variation between the records of stations not very far removed from one another, for example, Genoa, Marseilles, and the St. Bernard, seemed unaccountable, except it was chiefly due to differences in elevation.

Mr. SYMONS considered Mr. Tripp's rainfall table was most valuable, especially as showing the relation between extremes and means. As regarded Dr. Wolff's sun-spot cycle figures, he would much like to know from what epoch the 11·11 year period was supposed to be calculated.

Mr. TRIPP (in reply) said that he had been interested in noting, in papers written on the subject, great similarity in dates of culmination with those in his paper, not only in South Africa, but in different parts of the globe, but he did not consider that speaking of the 11·11 year period of sun-spots was quite accurate, as the intervals between the successive culminations varied from 8 to 16 years, and, so far as he could see, it certainly did not seem that any particular period was established to within a few years, except as an average year of precipitation at the St. Bernard; and it was also the wettest recorded at Barnaul. He considered that the division into years sometimes interfered with the due recording of culminations, but some division of time must be taken, and he had therefore adopted the usual one. He had not given the elevation of the stations, because the places were well-known. It was remarkable that the three stations, Marseilles, Genoa, and the St. Bernard, each had a great range of rainfall.

Mr. ELLIS remarked in regard to the sun-spot question, that Wolff discussed the observations of sun-spots through a great number of years, and determined therefrom the epochs of maximum and minimum. He found the average period to be 11·11 years, but with considerable irregularity in the recurrence of the individual epochs, some being much accelerated, and some much retarded, as compared with the average. We cannot take any particular epoch and carry it backwards and forwards by 11·11 years, or its multiples, and consider that such, as it were, fictitious epochs can supersede, or be in any way preferable to those deduced directly from observation, and he was surprised to hear that periods of excessive rainfall were thought to fall in better with such epochs. The sympathetic relation existing between sun-spots and terrestrial magnetism is a thing about which there is no question, but the magnetic phenomena fall in with the sun-spot phenomena as actually observed. The irregularities in both phenomena are similar, one proof indeed of sympathetic relation. And it is only reasonable to suppose that, if any corresponding relation exists between sun-spot and meteorological phenomena, it would similarly become evident by agreement between the facts as observed.

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# MUTUAL INFLUENCE OF TWO PRESSURE PLATES UPON EACH OTHER,

## And Comparison of the Pressures upon Small and Large Plates.

BY W. H. DINES, B.A., F.R.Met.Soc.

[Received April 1st.—Read May 21st, 1890.]

IN May 1889 I communicated to the Society the result of some experiments on Wind Pressure, and some interest was excited by the fact that eight circular holes, each of 1 square inch section, bored in a foot pressure plate, did not appreciably lessen the pressure. A request was made by some of the Fellows that I would, if possible, extend the experiment, and accordingly the following experiments have been made.

Inasmuch as boring holes and covering them up with a movable shutter was found rather inconvenient, another plan was adopted. Two precisely similar strips of wood 4 feet long by 3 inches broad were obtained, and arrangements were made so that they could be mounted on the whirling machine side by side, either with the long edges in contact, thus presenting a plate 4 feet long by 6 inches broad or with an open space of any width up to 18 inches between them.

The pressure was determined in the manner described in a former paper.[1]

Calling the pressure upon one of the strips taken alone, 50, the following figures show the pressures corresponding to various widths of open space between the strips :—

[1] *Quarterly Journal*, Vol. XV. p. 182.

| | | | |
|---|---|---|---|
| With edges in contact | ... | pressure | 79 |
| ,, 1 in. apart | ... | ,, | 91 |
| ,, 2 in. ,, | ... | ,, | 97 |
| ,, 4 in. ,, | ... | ,, | 99 |
| ,, 6 in. ,, | ... | ,, | 100 |

It will be seen by these figures that the strips cease to influence each other appreciably as soon as they are separated by their own width, and also that when they are placed with a gap 1 inch wide between them, the pressure would hardly be altered by filling up the gap and making one solid plate 7 inches wide. This latter result affords a proof of the accuracy of the preceding experiment with the plate with the holes in it. The figures are based on the results of about 50 experiments.

I have also made experiments upon the effect of placing one of these strips edgewise to the wind in the neighbourhood of the other. The arrangement is shown in the following diagram, which represents a section, the wind coming from the right.

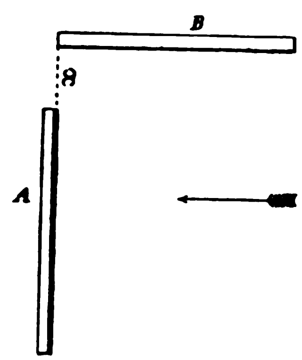


FIG. 1.

Taking 50, as before, for the pressure upon the strip A, when exposed by itself, and $x$ as its distance from B, the pressure when B and A are in contact will be represented by 55, and on separating the strips this value seems to decrease uniformly, until when $x$ = from 9 to 10 inches, the influence of the second plate B becomes inappreciable. If we suppose the wind direction to be reversed so that B is behind A, then it (B) appears to lessen the pressure upon A when placed near it, but its influence ceases at a shorter distance and becomes inappreciable at about 4 inches. These results are based on about 40 experiments.

Turning now to the effect of the size of a pressure plate, which is a subject of considerable importance, and one on which experiments are urgently required, since it has long been a disputed question whether the pressures were proportionally greater or less upon the larger plate.

Experiments made upon the whirling machine at Hersham have led me to suppose that the greater the plate the less proportionally is the wind pressure

upon it, but it is only comparatively small plates with which experiments can be made in this way. Hence I have endeavoured to balance larger surfaces of different sizes against each other by placing them at the ends of levers of different lengths and exposing them to the natural wind. Three plates were used—the first, 6 feet by 7 feet; the second, 3 feet by 3 feet; and the third, 1 foot 6 inches by 1 foot 6 inches. The large plate, 6 feet by 7 feet, was connected with the 3 feet plate by two long thin boards placed edgewise, so that the plates, but not the boards, might catch the wind, the centres being 12 feet 9 inches apart. The two plates thus connected were then raised to the top of a pole 12 feet high, the pole forming a pivot round which they could turn, the plates being one on each side of the pole but at different distances from it. By arranging so that the larger plate might be near the pole, and the smaller one at some distance from it, it was found possible to make the wind pressure upon the smaller plate just balance the pressure upon the larger one, so that when the wind met them both perpendicularly there was no tendency for the arrangement to turn either way. This was found to be the case when the centre of the larger plate was 2 feet 9 inches from the pole and the centre of the smaller plate 10 feet.

The larger plate contains 42 square feet and the smaller 9 square feet, so that if we take 10 feet for the distance of the smaller plate from the pole, the centre of the larger plate ought to be $\frac{90}{42}$ feet, *i.e.* a little under 2 feet 2 inches, instead of 2 feet 9 inches. Hence this experiment shows that the pressure per square foot upon the larger plate is only 78 per cent. of that upon the smaller.

Taking the 3 feet by 3 feet, and the $1\frac{1}{2}$ feet by $1\frac{1}{2}$ feet plates, and connecting them in the same way, the corresponding distances were found to be 1 foot $4\frac{5}{8}$ inches and 4 feet $10\frac{1}{2}$ inches, giving the pressure per square foot on the larger plate as 89 per cent. of that upon the smaller.

I found a decided difficulty in adjusting the equilibrium, but that was probably due to the want of a good exposure. The plates were exposed in a level field 20 yards from trees of any kind, and 50 yards from trees above 20 feet high; the wind direction, however, was constantly shifting through an angle of 90°. Changing the distances from the pole a few inches made a marked difference in the positions taken up, so that I see no reason to doubt the accuracy of these results.

The pressures upon the edges of the connecting boards have in both instances been neglected.

It seems probable that a decrease of pressure per square foot with an increase of size may be taken as a general rule. I was led to think from the result of experiments made last year (*Quarterly Journal*, Oct. 1889) that the pressure upon a plate 6 inches in diameter was proportionately less than upon a foot plate, but I now believe that my conclusion was wrong, the greater pressure upon the foot plate being probably caused by an eddy from the frame of the apparatus used for mounting the plates. The edge of the larger plate being nearer the frame, it seems reasonable to conclude that it would be more affected than the other.

With this exception, all the experimental evidence is in favour of the rule, and I cannot help thinking that there are very few large buildings which are capable of withstanding the great pressure sometimes recorded by small pressure plates. I ought, however, to add that some of these high pressure records are perhaps due to instrumental defects.

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# On the Variations of Pressure caused by the Wind blowing across the Mouth of a Tube.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received April 1st.—Read May 21st, 1890.]

A WHIRLING MACHINE seems to afford special facilities for experimenting with this type of anemometer, since it is easy to run a fine tube from the end of the long arm to the centre of the machine, and measure, by the difference of level of a coloured liquid in a U-shaped glass tube, placed at the centre, the variations from the normal value of the pressure, which are caused by the motion of the air across the other end of the tube.

A piece of brass tube, 1 inch diameter and 6 inches long, was obtained and mounted at the end of the long arm, so that it could point in any direction, its mouth being 28 feet from the axis of the whirler. A piece of $\frac{1}{8}$ inch composition tube, of the kind used for pneumatic bells, was brought from the brass tube to the centre of the machine and ended in a U-shaped gauge. On the machine being turned, the motion of the air across the mouth of the brass tube caused a variation of the air pressure within it, which variation being transmitted through the connecting tube, was shown on the gauge at the centre. When the machine is in motion the pressure is not transmitted to the centre without change, but is altered by the centrifugal force acting upon the air inside the tube; the difference thus caused can however be found with perfect accuracy. If a horizonal tube AB, $l$ ft. long, filled with liquid, is turned with angular velocity $\omega$ about a vertical axis through A, there will be a difference of pressure between A and B, which will be equivalent to a head of $\frac{l^2\omega^2}{2g}$ ft. of the same liquid. When the tube is 28 ft. long this difference is considerable; but air being very light compared with water and the tube being full of air, it is easy to balance it by a shorter tube containing water. It will be found that the difference in pressure thus caused in a tube 1 ft. long containing water is equal to the difference in pressure caused in a tube 28 ft. long containing air, the air being taken at standard temperature and

pressure; and hence allowance for this action was obtained by making the horizontal branch of the U tube 1 ft. long.

Having found the principle of using the centrifugal force to measure wind so convenient in other experiments, I have used the same plan again here. Fig. 1 shows the arrangement which has been used. A B and C are three glass tubes containing coloured water, in communication with each other. B is fixed and placed at the centre of the whirler, but the distances of A and C from B are

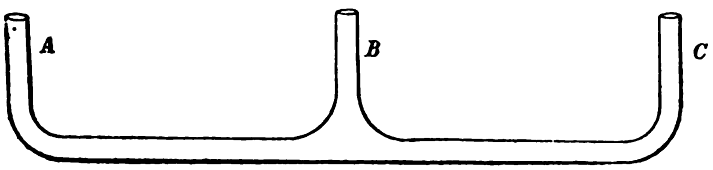


FIG. 1.

adjustable at pleasure; the communication being made in fact by flexible india-rubber tube. The pipe from the end of the long arm is connected with the top of B by an air-tight joint, and A and C are open to the air. A zero line is marked on B, and the experiments were made by adjusting the distances of A and C from B, so that rotation of the whirler caused no change in the level of the liquid in B. One pipe, either A or C, would have done, but in that case B must have been accurately placed at the centre of the whirler; using two pipes at equal distances from B a small error of this kind is eliminated. The two pipes are also convenient, because the small change in level which is almost inevitable as the machine goes round, does not of itself move the liquid from the zero mark on B. As stated above, when A B = B C = 1 ft., the motion does not alter the level.

The following values have been determined:—I. Brass tube vertical, so that the air blows across the mouth.

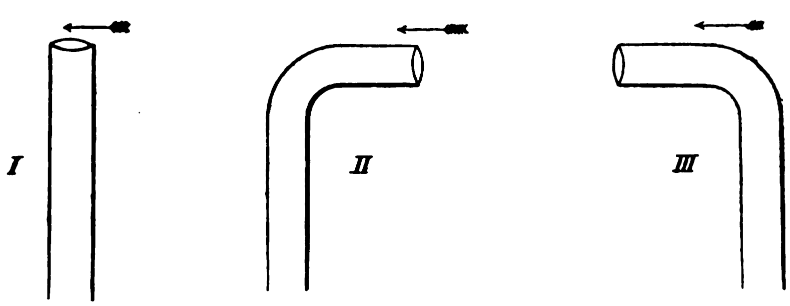


FIG. 2.

For equilibrium A C = 35¼ inches.

A very slight inclination of the tube either way causes a decided falling off in the partial vacuum produced.

II. Tube horizontal, or air blowing straight down the mouth of the tube. For equilibrium A C = 2 ins.

In this position a considerable inclination, about 10° to 15°, is admissible before an appreciable change of pressure occurs.

III. Tube horizontal, but air blowing away from mouth.

For equilibrium A C = 26 ins.

In this position a slight change in the angle increases the vacuum produced.

To reduce these values to a difference of water level, we notice that when the velocity is 60 miles an hour, one complete turn is made in two seconds, and, therefore, $\omega = \pi$. Substituting for $l$ in the expression $\frac{l^2\omega^2}{2g}$ and remembering that in each case a pressure of $\frac{\omega^2}{2g}$ must be added to compensate for the effect of the centrifugal force upon the air in the connecting tube, we find that

In case I. we have a partial vacuum of 2·10 ins. of water.
,, II. ,, an increase of pressure of 1·82 in. of water.
,, III. ,, a partial vacuum of 0·32 in. of water.

These values refer to a velocity of 60 miles an hour; at half the pace they will only be ¼ as great; at ⅓ the pace only ⅑ as great, and so on, following the ordinary law with regard to wind pressure, viz. that the pressure varies as the square of the velocity.

The same values were found to hold in the case of a tube of ½ in. diameter.

If two thin discs be placed horizontally, one a little above, and one a little below the mouth of the tube, the partial vacuum (case I.) is reduced, but the arrangement is not so susceptible to a small change of inclination as the open mouth is. With two discs, 4 ins. diameter, one ⅝ in. below and the other ⅝ in. above the open mouth, the partial vacuum at 60 miles an hour is 1·44 in. of water.

I have also taken the opportunity to determine the vacuum at the back of a pressure plate. With a foot plate, square, the partial vacuum close to the back at the centre is ·89 in. of water at 60 miles an hour, and the increase of pressure in front at the centre is 1·82 in.; the same value which is given by the wind blowing down the tube.

The simplicity of this kind of anemometer is of great advantage; it does not seem capable of registering any low velocity, but that is a defect common to most pressure instruments, because the pressure at low velocities is so very small. For strong winds, however, it seems very suitable, and the arrangement is greatly recommended by the fact that the head can be placed in any position, however inaccessible to the daily observer, and communication made with the registering part by a long tube. According to the well-known law of Hydrostatics the tube, however long, will faithfully and immediately transmit any variation of pressure.

## DISCUSSION.

Mr. LAUGHTON said that the ingenuity of Mr. Dines's apparatus had impressed him almost more deeply than even the very remarkable and valuable results which had been obtained by it. There was one point in the comparison of the pressures on plates of different sizes which appeared especially curious, the difference, namely, in the percentage of variation: it almost seemed to show that nothing can be deduced; that every result will have to be determined by independent observation. He should like to ask Mr. Dines whether the results given in the paper were to be held true for all wind forces, or whether they might be expected to vary with the strength of the wind? What had been said about the variation in the vacuum of anemometers of the Hagemann type, caused by an inclination of the tube, was a great blow to himself; a shattering of his idols, in fact. He had long cherished a hope that this type of anemometer might be adapted to use on board ship, so that the indications of a tube running up one of the masts might be read in the captain's cabin. This would now appear to be impossible; unless, indeed, it should be found practicable to have the nozzle of the tube fitted in gimbals, so as to remain always in the vertical position.

Mr. SYMONS suggested that the amount of edge in the plates used might have something to do with the results obtained; for when this factor was taken into consideration the figures appeared to follow a more regular sequence. He entirely agreed with Mr. Dines in believing that very few, if any, buildings could resist the enormous wind pressures frequently registered by anemometers.

Mr. BIRCH inquired whether Mr. Dines could state the actual pressure and velocity when the relation between the resistance caused by the various arrangements of plates was established? and over what range of velocities, if any, he thought that relation might be expected to hold good?

Mr. BUCHAN remarked on the great ingenuity of Mr. Dines's apparatus, and said that as regarded wind observations, he had never yet seen any possibility of discussing such observations except for direction only. He was much interested to find that the pressure proportionately increased as the area of the surface of the plate diminished. He described some experiments which he and Prof. Darwin had seen Mr. Dines make concerning the distribution of pressure upon surfaces placed at various angles to the wind, and stated that when the surfaces were inclined at an angle of 56° it was found that a larger pressure was obtained than when the exposure was normal.

Mr. MUNRO said that similar results to those obtained by Mr. Dines had been ascertained from the observations made at the Forth Bridge Works. Two plates were exposed, the large one being made of wood, and it was found that the pressure per foot on the larger plate was always only about half what it was on the smaller one. The great question to solve was, what was a reasonable or sufficient size for such pressure plates?

Mr. CHATTERTON inquired what was the maximum velocity which the tube arrangement of Mr. Dines could record?

Mr. SYMONS said that he believed that it was on record that when the building for the Great Exhibition of 1851 was being constructed, a wind pressure of 15 lbs. on the square foot was considered to be the greatest strain it would have to withstand.

Mr. ELLIS was glad to find that Mr. Dines was continuing his very valuable experiments, and further said that he should like to testify to the difficulty of dealing with pressure instruments as regards the registration of great pressures. In the Greenwich Osler anemometer the pressure plate was formerly connected to the recording pencil by means of a copper wire passing down the long vertical tube reaching from the anemometer to the recording table, an arrangement which he never liked, and in the year 1882 at his suggestion the copper wire was replaced by a fine brass chain, since which time the greatest pressure registered in gusts has not exceeded about 30 lbs. on the square foot, in some years 20 lbs. only or a very little more had been registered, whilst in the year 1889 the greatest pressure recorded was only 15 lbs. He did not believe in the great pressures at times registered at Greenwich previous to the year 1882, and a cautionary note in regard to these pressures was inserted in the Introduction to the Greenwich volume for 1886 and following years, as well as in the Report on the

Royal Observatory for the year 1868, which appears in the *Quarterly Journal* of the Society (Vol. XV. p. 99). He did not mean to say that greater pressures might not be experienced in the country elsewhere. It always seemed to him that the pressure plate being deflected in heavy gusts with great suddenness, the copper wire at such times acted irregularly, but the brass chain, always in tension, appeared to work more smoothly, the movements of the recording pencil better representing those of the pressure plate, whilst the action was otherwise more delicate, as was shown by the greater excellence of the register of very small pressures. For moderate pressures he considered that the record had been always fairly reliable. In the early years of the Osler record 25 lbs. on the square foot was thought to be an extreme pressure; in intermediate years greater pressures certainly became registered, but since the year 1882 there has been no further instance of apparently excessive pressure. In regard to the question by a previous speaker why the presumed effect of the copper wire was not sensible in the experiments from time to time made for determination of the pressure scale, he would remark that the hanging of a definite dead weight on to the pressure plate is a very different thing to the sudden and fierce action of the wind on the plate in heavy gusts, which could scarcely be artificially imitated.

Mr. Tripp remarked that according to his observations of recent records of rainfall, the 'fifties' and 'sixties' appeared to have been years of absence of cyclonic disturbances, while during the 'seventies' such disturbances seemed to have been in excess. It would be interesting to know whether the curve of wind pressure for these years coincided with these inferences, as it had been remarked by Mr. Symons that there had been great differences in the estimation at different periods of the amount of allowance to be made for such pressures in buildings, and the speaker thought that these corresponded somewhat with the above observations of rainfall.

Mr. Dines said that he must thank the Society for the kind way in which they had received his paper. With regard to Mr. Laughton's question, he had noticed that the percentages between the two pairs of plates were different, and could not explain it, but he thought it would be very desirable that some one who could get a good exposure should repeat the experiments, since he had worked under considerable difficulties in that respect. He saw no reason to doubt that the relations between the pressures held for all velocities. He did not think it would be possible to use the tube form of anemometer on board ship, because the mouth of the tube being moved about by the rolling of the vessel, it would not be possible to say what proportion of the pressure or vacuum produced was due to the wind, and what was due to the rolling. It might be possible to design some form of registering apparatus which would show the small differences of pressure due to light winds, but he thought that when such slight differences as $\frac{1}{10}$ of an inch were concerned, the apparatus must be very delicate and liable to error. He agreed with Mr. Symons that an increase of the perimeter of a plate proportionally to the area did increase the pressure, but he could give no reason for such being the case. Mr. Buchan had referred to the action of the wind upon a sloping surface, and had suggested that experiments should be made upon larger surfaces. The whirling machine at Hersham would not carry much beyond a foot plate, because the larger sizes required much stronger apparatus and consequently much greater weight. Also a very powerful engine would be required. It required nearly 2-horse power to move a foot plate through the air at 60 miles an hour, apart from the long arm and supports, and the 4-horse power engine which he had at Hersham could not give a greater velocity than 50 miles an hour to the end of the whirling machine when the foot plate was used. He (Mr. Dines) had calculated that at least 150 h. p. was used by a locomotive engine running at 60 miles an hour in overcoming the air resistance upon itself apart from the tender and carriages, and he could not understand why some of this loss was not avoided, as it easily might be. Answering Dr Tripe, he said that he did not believe that there was any peculiarity about circular plates, he thought they would follow the same rule as other shapes; in all the cases which he had tried, namely circles containing areas of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, and 1 ft., the pressure had been nearly the same as upon square plates of the same area. Mr. Chatterton had inquired whether the tube form of anemometer would answer for high velocities; he thought it would answer admirably, and

that the rule of pressure varying as the square of the velocity might be trusted to hold for the whole range of possible wind velocities, excepting perhaps for the very lowest. Mr. Ellis had referred to the momentum of pressure plates. He believed that the high pressures recorded were mostly due to the momentum of the moving parts carrying the index beyond its proper position; and Mr. Ellis's remarks about the Greenwich anemometer had confirmed his belief. Mr. Strachan had remarked that the subject of wind pressure generally was one of mechanics, and no doubt it was so. This special branch of mechanics, however, viz. hydro-dynamics, was so difficult, and the mathematical analysis required so complicated and abstruse, that personally he could not attempt to approach the subject from that side, and he believed that it was only in a few limited cases that a rigorous mathematical solution could be obtained.

In conclusion, he should like to say that he thought the tube form of anemometer a very good one indeed, but there were two points about it which must not be overlooked. It was essentially a pressure and not a velocity instrument, and its indications of velocity would certainly depend upon the density of the air. Secondly, if the registering part be placed away from the head, as must generally be the case, the communication must be made by means of two tubes, in such a manner that the actual pressure of air in the room in which the registering part is placed cannot affect the instrument. Otherwise, the opening of a door or window, or even stirring up the fire and increasing the draught up the chimney, would appear on the record as a change of wind velocity.

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## On the Difference produced in the Mean Temperature derived from Daily Maximum and Minimum Readings, as depending on the time at which the Thermometers are read.

By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory, Greenwich.

[Received May 17th.—Read June 18th, 1890.]

The maximum and minimum readings of air temperature which appear in the *Greenwich Observations* are those of the maximum and minimum thermometers on the revolving stand, and refer to the civil day from midnight to midnight. When the Greenwich maximum and minimum temperatures were first communicated to the Royal Meteorological Society for insertion in the *Meteorological Record*, in the table giving results for London stations, they were supplied as thus tabulated for the Greenwich volume, and as indeed previously also appearing in the *Weekly Return* of the Registrar General. But on this arrangement, the separate daily readings were not comparable with those of the other London stations, since the latter were tabulated according to the plan adopted by the Society for stations termed "Climatological." In consequence of which the Greenwich values, since the beginning of the year 1886, have, at the request of the Society, been supplied according to the climatological plan, that is to say the reading of the

maximum thermometer for the twenty-four hours ending 9h. a.m. is entered to the preceding civil day, and the reading of the minimum to the same civil day.

Without consideration of the matter it might be supposed that, with values tabulated according to the two methods described, the monthly means of the maximum and minimum readings would, on the average, be similar on both systems. But on making the necessary comparison, a perceptible difference, almost always in the same direction, was found to exist, not only between the means of the maximum readings, but also between the means of the minimum readings. This, it appeared to me, might have sufficient interest for the Fellows of the Royal Meteorological Society to make it desirable to communicate to the Society the results of a comparison made for the four years 1886 to 1889. The differences found to exist between the two sets of means are given in Table I., from which Table II. is formed showing the differences in the mean temperature of the different months thereby produced, as derived from the mean of the maximum and minimum readings.

It will, of course, be understood that the differences given in the Tables are differences of indication of the same maximum and the same minimum thermometer (those of the revolving stand) arising simply from difference in the method of tabulation.

TABLE I.

| Month. | Excess of Climatological Maximum above Civil Day Maximum. | | | | | Excess of Climato'ogical Minimum above Civil Day Minimum. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1886. | 1887. | 1888. | 1889. | Mean. | 1886. | 1887. | 1888. | 1889. | Mean. |
| | ° | ° | ° | ° | ° | ° | ° | ° | ° | ° |
| January .. | +0·2 | +0·2 | +0·4 | 0·0 | +0·20 | +0·3 | −0·5 | −0·5 | −0·4 | −0·27 |
| February .. | 0·0 | +0·1 | 0·0 | +0·1 | +0·05 | −0·1 | +0·3 | +0·3 | 0·0 | +0·13 |
| March .... | 0·0 | +0·2 | +0·4 | 0·0 | +0·15 | +0·3 | +0·5 | +0·5 | +0·1 | +0·35 |
| April ...... | +0·3 | 0·0 | +0·2 | +0·1 | +0·15 | +0·8 | +0·4 | +0·3 | +0·3 | +0·45 |
| May ...... | +0·2 | +0·2 | +0·2 | 0·0 | +0·15 | +0·7 | +0·5 | +0·7 | +0·5 | +0·60 |
| June ...... | +0·1 | +0·2 | 0·0 | +0·3 | +0·15 | +0·4 | +0·5 | +0·1 | +0·3 | +0·33 |
| July ...... | +0·3 | 0·0 | +0·7 | +0·1 | +0·27 | +0·6 | +0·5 | 0·0 | +0·3 | +0·35 |
| August .... | 0·0 | 0·0 | +0·3 | 0·0 | +0·08 | +0·5 | +0·2 | +0·9 | +0·5 | +0·52 |
| September | +0·1 | 0·0 | −0·1 | 0·0 | 0·00 | +1·6 | +0·7 | +1·0 | +0·9 | +1·05 |
| October .... | 0·0 | 0·0 | 0·0 | 0·0 | 0·00 | +0·6 | +0·3 | +0·3 | +0·5 | +0·42 |
| November .. | +0·1 | +0·4 | −0·2 | −0·1 | +0·05 | +0·2 | +0·5 | +0·4 | +0·4 | +0·38 |
| December .. | +0·1 | +0·3 | +0·4 | +0·8 | +0·40 | −0·1 | −0·3 | +0·3 | −0·1 | −0·05 |
| Means .... | +0·12 | +0·13 | +0·19 | +0·11 | +0·14 | +0·48 | +0·30 | +0·36 | +0·28 | +0·36 |

Examining the various columns of Table I. it is seen how persistent is the tendency to difference in one direction. Especially is this so as regards the means of the minimum readings, which not only differ more than do those of the maximum readings, but differ also by amounts that vary considerably with the time of year, being apparently greatest in spring and autumn, less in summer, and least, being indeed reversed in direction, in winter. The difference between the means of the minimum readings in the month of September is especially remarkable, particularly in the year 1886. In explanation of these differences

TABLE II.

| Month. | Excess of Climatological Monthly Mean Temperature above Civil Day Monthly Mean Temperature. | | | | |
|---|---|---|---|---|---|
| | 1886. | 1887. | 1888. | 1889. | Mean. |
| | ° | ° | ° | ° | ° |
| January | +0·25 | −0·15 | −0·05 | −0·20 | −0·04 |
| February | −0·05 | +0·20 | +0·15 | +0·05 | +0·09 |
| March | +0·15 | +0·35 | +0·45 | +0·05 | +0·25 |
| April | +0·55 | +0·20 | +0·25 | +0·20 | +0·30 |
| May | +0·45 | +0·35 | +0·45 | +0·25 | +0·37 |
| June | +0·25 | +0·35 | +0·05 | +0·30 | +0·24 |
| July | +0·45 | +0·25 | +0·35 | +0·20 | +0·31 |
| August | +0·25 | +0·10 | +0·60 | +0·25 | +0·30 |
| September | +0·85 | +0·35 | +0·45 | +0·45 | +0·52 |
| October | +0·30 | +0·15 | +0·15 | +0·25 | +0·21 |
| November | +0·15 | +0·45 | +0·10 | +0·15 | +0·21 |
| December | 0·00 | 0·00 | +0·35 | +0·35 | +0·18 |
| Means | +0·30 | +0·22 | +0·27 | +0·19 | +0·25 |

it is to be remembered, first as regards the maximum, that the daily reading for the twenty-four hours ending 9h. a.m. being, according to the climatological plan, placed to the preceding civil day, if the temperature between midnight and 9h. a.m. should in any case be higher than that for the twenty-four hours ending with midnight, the recorded climatological maximum will be higher than that for the civil day ending at midnight, and a few instances of this kind occurring during a month tend to throw up the climatological mean as compared with the civil day mean. On the other hand, as regards the minimum, if the temperature between 9h. a.m. and midnight should fall below that for the twenty-four hours ending with 9h. a.m., the minimum recorded for the civil day will be lower than that recorded on the same day on the climatological plan, and this occurring occasionally during a month tends to make the climatological mean again relatively high. So that the climatological mean maximum and minimum both become increased as compared with those given by tabulation according to the civil day. Or the mean temperature as derived from the mean of the maximum and minimum readings differs, according to the system of tabulation employed, in the way shown in Table II.

There is a converse case, both as regards maximum and minimum, not apparently occurring so frequently as the cases before mentioned, excepting in winter, and consequently generally insufficient to compensate for their influence on the mean values. For instance, the temperature may happen to be higher between midnight and 9h. a.m. than at any time during the twenty-four hours ending with the following 9h. a.m., in which case the civil day maximum would be the higher of the two. Or the temperature may be lower between 9h. a.m. and midnight than during the twenty-four hours ending with the following midnight, in which case the climatological minimum will be the lower of the two.

The anomalies mentioned arise only when the diurnal variation of

temperature is abnormal. When the daily maximum occurs at the ordinary time, in early afternoon, and the minimum shortly before sunrise, the maxima and minima, on both the systems of tabulation mentioned, would, in the absence of great fluctuations of temperature from day to day, be in this country generally similar. The cases of abnormal change first mentioned are those that more frequently occur, excepting in winter, whilst those afterwards spoken of are more especially prevalent in winter.

As respects the great difference between the means of the minimum readings in September 1886, I have gone over the numbers again, and find the difference to be really correct, and due to the instances in which the temperature before midnight fell below that of the preceding night. On one day especially, September 10th, the minimum for the twenty-four hours ending 9h. a.m. was 61°·1, the climatological minimum for the day, but before the midnight following the temperature fell to 46°·0, which was the minimum for the day according to civil reckoning. Thus 0°·5 of the difference (1°·6) between the monthly means was produced by this one case.

It may be further pointed out, as concerns the variation between the means of the minimum readings during the course of the year (last column of Table I.) that the greatest differences occur at those periods of the year which, on the average, are most free from cloud, spring and autumn, whilst the negative differences are found during the most cloudy period, that of winter.

The tabulation of the maximum and minimum readings according to the plan adopted for Second Order stations, by which the maximum and minimum readings for the twenty-four hours ending 9h. p.m. are placed to the day of reading, seems likely to give mean values more in accordance with those found from tabulation according to the civil day, but I am not at present prepared to offer any evidence on this point.

## ADDENDUM.

Reference is made in the preceding paper to the system of registering the maximum and minimum temperature adopted for stations of the Second Order (according to which they are tabulated for the twenty-four hours ending 9h. p.m.) as likely to give means more in accordance with those found from values referring to the civil day, but no evidence on the point is given. It however happens that the observations of the thermometers in a Stevenson screen and on the roof of the Magnet House at the Royal Observatory are recorded on the Second Order station plan, and as their daily readings have been compared with the corresponding readings of the ordinary maximum and minimum thermometers on the revolving stand, the monthly means of the observed differences, if applied to the monthly means of the Stevenson screen and roof thermometers, enable us to infer therefrom the monthly means of the ordinary maximum and minimum thermometers on the revolving stand according to the Second Order station system, and so

compare them with means of readings of the same thermometers applying to the civil day, midnight to midnight. In these results Sundays are omitted, the Stevenson screen and the roof thermometers not being read on Sundays, but as the question is one of differences, this does not signify, so long as the same days are used in all cases. Such results are available for the years 1886, 1887, and 1888, but not for 1889, the discussion of the work for that year not being yet complete. By the process described, apparently involved, but under the circumstances really saving labour, it will be seen that in the annexed tables we have, as before, simply differences of indication of the same maximum thermometer and the same minimum thermometer (those of the revolving stand) as depending entirely on the method of tabulation.

TABLE III.

| Month. | Excess of Second Order Maximum above Civil Day Maximum. | | | | Excess of Second Order Minimum above Civil Day Minimum. | | | |
|---|---|---|---|---|---|---|---|---|
| | 1886. | 1887. | 1888. | Mean. | 1886. | 1887. | 1888. | Mean. |
| | o | o | o | o | o | o | o | o |
| January ........ | +0·1 | +0·2 | +0·2 | +0·17 | +0·2 | 0·0 | −0·2 | 0·00 |
| February ........ | −0·1 | 0·0 | +0·2 | +0·03 | +0·1 | +0·75 | +0·35 | +0·40 |
| March .......... | −0·1 | −0·05 | +0·25 | +0·03 | 0·0 | +0·3 | +0·1 | +0·13 |
| April ............ | −0·1 | +0·15 | 0·0 | +0·02 | +0·3 | +0·3 | +0·3 | +0·30 |
| May ............ | +0·1 | 0·0 | +0·1 | +0·07 | +0·5 | +0·65 | +0·5 | +0·55 |
| June ............ | +0·1 | +0·05 | 0·0 | +0·05 | +0·5 | +0·55 | +0·1 | +0·38 |
| July ............ | 0·0 | 0·0 | +0·05 | +0·02 | +0·4 | +0· 5 | +0·2 | +0·37 |
| August .......... | 0·0 | +0·05 | 0·0 | +0·02 | +0·5 | 0· 0 | +0·6 | +0·37 |
| September ...... | 0·0 | 0·0 | 0·0 | 0·00 | +0·7 | +0· 6 | +0·4 | +0·57 |
| October .......... | +0·1 | +0·05 | 0·0 | +0·05 | +0·1 | +0· 3 | +0·25 | +0·22 |
| November ...... | +0·1 | +0·2 | +0·2 | +0·17 | 0·0 | +0·15 | +0·3 | +0·15 |
| December ........ | +0·3 | +0·45 | +0·1 | +0·28 | −0·6 | +0· 2 | +0·1 | −0·10 |
| Means ........ | +0·04 | +0·09 | +0·09 | +0·08 | +0·22 | +0·36 | +0·25 | +0·28 |

ROYAL OBSERVATORY, GREENWICH.

**Excess of Values of Climatological Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1889.**

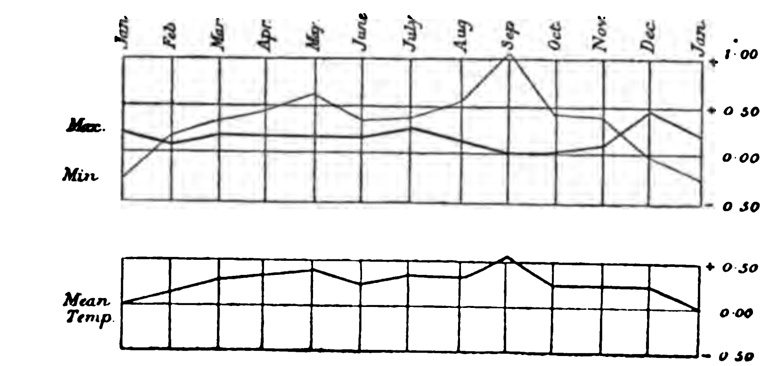


Fig. 1.

TABLE IV.

| Month. | Excess of Second Order Monthly Mean Temperature above Civil Day Monthly Mean Temperature. | | | |
|---|---|---|---|---|
| | 1886. | 1887. | 1888. | Mean. |
| January | +0°·15 | +0°·10 | 0°·00 | +0°·08 |
| February | 0·00 | +0·38 | +0·28 | +0·22 |
| March | −0·05 | +0·12 | +0·17 | +0·08 |
| April | +0·10 | +0·23 | +0·15 | +0·16 |
| May | +0·30 | +0·32 | +0·30 | +0·31 |
| June | +0·30 | +0·30 | +0·05 | +0·22 |
| July | +0·20 | +0·25 | +0·12 | +0·19 |
| August | +0·25 | +0·02 | +0·30 | +0·19 |
| September | +0·35 | +0·30 | +0·20 | +0·28 |
| October | +0·10 | +0·18 | +0·13 | +0·14 |
| November | +0·05 | +0·17 | +0·25 | +0·16 |
| December | −0·15 | +0·33 | +0·10 | +0·09 |
| Means | +0·13 | +0·23 | +0·17 | +0·18 |

ROYAL OBSERVATORY, GREENWICH.

**Excess of Values of Second Order Maximum, Minimum and Mean Temperature, above the corresponding Civil Day values, 1886 to 1888.**

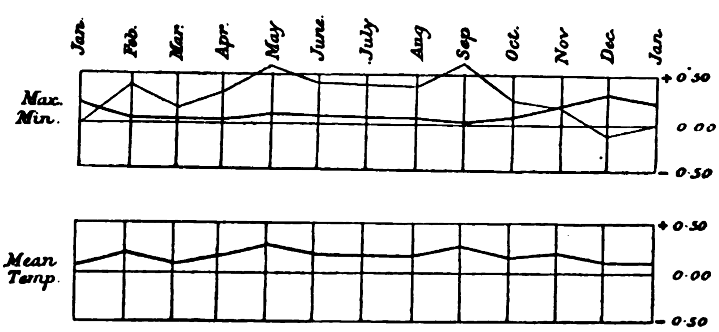


FIG. 2.

It thus appears that the differences between the Second Order system means and the civil day means are of the same general character as in the comparison given in the paper between the Climatological means and the civil day means, but are less in amount. There is not, however, such marked variation between the means of the minimum readings in different parts of the year as is shown in the comparison with the Climatological means.

The mean monthly numbers of Tables I., II., III., and IV., are graphically exhibited in the accompanying diagrams (Figs. 1 and 2).

## DISCUSSION.

The PRESIDENT (Mr. Latham) asked if the same instruments were used for all the observations.

Mr. BAYARD said that he was much interested in these comparisons. He had thought, when the question of the difference between the Climatological and Second Order observations had occurred to him, that it would be very slight, and certainly Mr. Ellis's results showed that the variation was not greater than might be due to what was termed 'personal equation.' Very few observers would agree precisely when reading the same thermometer to tenths of a degree.

Mr. C. HARDING inquired whether Mr. Ellis could give any idea of the number of occurrences of abnormal variations between the climatological and civil day maximum and minimum temperatures. He was surprised that the difference between the means was not greater, for he had found when using the Greenwich climatological temperatures, that they frequently differed considerably from the civil day values.

Mr. MARRIOTT said that he was very pleased indeed that Mr. Ellis had taken up this subject, because it bore so closely on the system of observations organised by the Society. The table of differences between the Second Order and Climatological temperatures was very striking, and he was glad to see that there was such close agreement. He then proceeded to explain on the blackboard the principles upon which the Climatological and Second Order Observations were made, and showed how abnormal variations in temperature produced the differences between the maxima and minima observed under the conditions of the two methods.

Mr. SYMONS said that as it was only the civil day readings that differed so largely from the climatological readings, the results of this paper seemed to point to the desirability of the Greenwich Observatory authorities adopting the ordinary meteorological day, either ending at 9 a.m. or 9 p.m.

Dr. TRIPE said that there was every reason to be satisfied with the results of this comparison. The system of Climatological stations organised by the Society was chiefly arranged to suit the convenience of a large number of observers who found it impracticable to take regular evening observations, and the close agreement between the results of observations made by the same instruments on this plan and of those made under Second Order conditions, proved the wisdom of the course taken in establishing these Climatological stations on their present basis. He should have expected more *plus* signs during February than were shown in Mr. Ellis's tables, as a rise in the temperature during the night is a rather common occurrence in this month.

Mr. ELLIS in reply said that the maximum and minimum thermometers on the revolving stand, in the Stevenson screen, and on the roof of the Magnet House, are really different instruments, but it would be seen that it was not the indications of these different instruments that come into comparison in the paper, the results given being simply differences of the means of readings of the maximum and minimum thermometers on the revolving stand, as depending on the method of tabulation: they were therefore strictly comparable. The differences are not in general large, but they are real, and not of the character of personal equation. As regards the number of times that the daily maximum and minimum readings, taken according to the climatological plan, differ from the readings on the civil day system, the numbers for the year 1886 have been counted, with the following result:—

| Month. | | Maximum differs on | Minimum differs on | Month. | | Maximum differs on | Minimum differs on |
|---|---|---|---|---|---|---|---|
| January | ... | 8 days. | 18 days. | July ... | ... | 8 days. | 7 days. |
| February | ... | 4 " | 7 " | August | ... | 1 " | 8 " |
| March | ... | 1 " | 11 " | September | ... | 1 " | 16 " |
| April | ... | 5 " | 10 " | October | ... | 8 " | 10 " |
| May | ... | 8 " | 8 " | November | ... | 6 " | 13 " |
| June | ... | 8 " | 10 " | December | ... | 11 " | 20 " |

Monthly mean temperatures (mean of maximum and minimum) on the climatological plan may be considered to be practically similar to means on the Second Order system. But both differ from the civil day means. Since, how-

ever, it has been authoritatively laid down that, at primary stations, maximum and minimum readings should be tabulated according to the civil day, ending with midnight, we cannot, as suggested, give up the civil day arrangement, although if thought desirable the monthly means of readings might be given in addition, according to the Second Order system and Climatological plan.

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## On the distribution of Barometric Pressure at the average level of the Hill Stations in India, and its probable effect on the Rainfall of the Cold Weather.

By W. L. DALLAS, of the Meteorological Office, Calcutta.

(Communicated by R. H. Scott, F.R.S.)

(Abstract.)

[Received May 6th.—Read June 18th, 1890.]

The author shows, by a comparison of the cold weather rainfall of India in January 1889 and January 1890, that whereas the former was in excess of the average over the greater part of North-western India and in Ceylon, the latter was very deficient in both quarters. On comparing the mean distribution of pressure in the two months as shown by stations on the plains, he finds that their main features are very similar, except that the general pressure was lower in the latter and drier year. In both years it was such as to produce a preponderance of anticyclonic winds. When, however, he compares the pressures at the hill stations (at elevations varying between 3,500 and 7,500 ft.) he finds that these afford evidence of baric gradients of very different intensities in the two years, and reversed in direction from those on the plains. According to the method of reduction adopted by the author, the gradients in January 1889 appear to be about double those prevailing in January 1890, and to this circumstance he attributes the greater prevalence of Southerly winds and rainfall in January 1889.

He also compares the barometric conditions, winds and rainfall of two storms that passed across Northern India in February 1889 and February 1890, and finds that at low levels their barometric features were remarkably alike, the rainfall being much heavier at the hill stations, while none fell in the Southern Punjab in the storm of the latter year, whereas in that of the former year it was more general on the plains. But in the barometric readings of the hill stations, he finds evidence of a very different distribution of pressure, and he considers that herein lay the explanation of the differences in the rainfall.

# ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL OBSERVATORY, GREENWICH, 1841-1889.

By WILLIAM ELLIS, F.R.A.S., of the Royal Observatory.

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[Received April 29th.—Read June 18th, 1890.]

Mr. Prince, of Crowborough Observatory, Sussex, having in his Meteorological Report for the year 1889 drawn attention to the greater prevalence of North-east winds which he has found to exist at Crowborough in recent years, I have thought that it would be interesting to put together the results derived from the records of the self-registering Osler anemometer of the Royal Observatory, Greenwich. The numbers contained in the annexed table are either copied or derived from those given in the annual volumes of *Greenwich Observations.* The results from 1841 to 1860 are given in an Appendix to the volume for 1860, and for the remaining years in the several annual volumes. Until 1869 the results are given for days, and since 1870 for hours. The day unit is, however, here retained for better comparison with Mr. Prince's values, or with those of other observers, that is to say the values for hours since 1870 have been divided by 24.

In considering this Table it would appear that in some of the earlier years the number of calm days is in excess of the true amount, arising probably from some rule having been adopted for the classification of days as calm which admitted too many, otherwise the same general balance of winds seems to be maintained throughout, the several means for 24 years and 25 years giving no indication of any great change in this respect, neither is there any appearance of change in late years such as Mr. Prince finds at Crowborough.

But to consider now the statements of Mr. Prince. He says, " The great preponderance of North-east wind over all other wind currents, and more particularly over that from the South-west, which has obtained during the last five years, has induced me to look through my journal since 1858 in order to ascertain whether I had a record of any similar condition of the principal wind currents of the South-east of England. For the thirty-one years, ending with 1889, I find only two instances in which the North-east has been in excess, viz. in the years 1864 and 1870."

The corresponding number of days of North-east and South-west winds for Crowborough and Greenwich in the years 1864 and 1870 are as follows :—

| Year. | | Crowborough. | | Greenwich. | |
|---|---|---|---|---|---|
| | | NE. | SW. | NE. | SW. |
| 1864 | ... | 104 | 89 | 48 | 108 |
| 1870 | ... | 107 | 88 | 65 | 96 |

NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS IN EACH YEAR 1841 to 1889, AS DERIVED FROM THE RECORDS OF THE SELF-REGISTERING OSLER ANEMOMETER OF THE ROYAL OBSERVATORY, GREENWICH.

| Year. | N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|---|
| 1841 | 40 | 19 | 22 | 9 | 49 | 112 | 60 | 17 | 37 |
| 1842 | 46 | 40 | 31 | 15 | 31 | 112 | 38 | 25 | 27 |
| 1843 | 42 | 44 | 22 | 8 | 18 | 102 | 37 | 29 | 63 |
| 1844 | 48 | 57 | 18 | 14 | 22 | 89 | 35 | 26 | 57 |
| 1845 | 30 | 49 | 11 | 13 | 43 | 104 | 43 | 38 | 34 |
| 1846 | 27 | 25 | 21 | 18 | 39 | 94 | 32 | 23 | 86 |
| 1847 | 41 | 23 | 16 | 4 | 55 | 111 | 36 | 10 | 69 |
| 1848 | 53 | 38 | 19 | 36 | 58 | 90 | 29 | 20 | 23 |
| 1849 | 59 | 54 | 20 | 23 | 39 | 102 | 35 | 22 | 11 |
| 1850 | 49 | 48 | 24 | 21 | 30 | 116 | 27 | 19 | 31 |
| 1851 | 52 | 39 | 21 | 20 | 28 | 100 | 37 | 25 | 43 |
| 1852 | 45 | 58 | 36 | 21 | 52 | 108 | 27 | 8 | 11 |
| 1853 | 43 | 65 | 16 | 27 | 28 | 86 | 32 | 27 | 41 |
| 1854 | 31 | 45 | 17 | 20 | 30 | 117 | 42 | 30 | 33 |
| 1855 | 56 | 74 | 23 | 17 | 25 | 84 | 30 | 26 | 30 |
| 1856 | 44 | 54 | 27 | 30 | 31 | 80 | 50 | 26 | 24 |
| 1857 | 21 | 58 | 28 | 27 | 33 | 119 | 34 | 21 | 24 |
| 1858 | 26 | 61 | 38 | 27 | 26 | 106 | 40 | 29 | 12 |
| 1859 | 31 | 54 | 16 | 29 | 25 | 128 | 40 | 31 | 11 |
| 1860 | 30 | 47 | 26 | 19 | 22 | 120 | 64 | 31 | 7 |
| 1861 | 26 | 43 | 29 | 17 | 22 | 119 | 59 | 25 | 25 |
| 1862 | 27 | 46 | 20 | 32 | 17 | 118 | 71 | 22 | 12 |
| 1863 | 21 | 33 | 20 | 24 | 22 | 138 | 60 | 28 | 19 |
| 1864 | 44 | 43 | 34 | 27 | 28 | 108 | 32 | 16 | 34 |
| 1865 | 40 | 30 | 18 | 28 | 24 | 97 | 47 | 22 | 59 |
| 1866 | 28 | 31 | 27 | 14 | 28 | 119 | 62 | 22 | 34 |
| 1867 | 43 | 40 | 29 | 21 | 37 | 119 | 41 | 26 | 9 |
| 1868 | 39 | 43 | 20 | 19 | 37 | 113 | 54 | 18 | 23 |
| 1869 | 38 | 51 | 24 | 26 | 27 | 112 | 50 | 27 | 10 |
| 1870 | 39 | 65 | 29 | 24 | 26 | 96 | 49 | 28 | 9 |
| 1871 | 37 | 50 | 38 | 31 | 36 | 100 | 47 | 17 | 9 |
| 1872 | 35 | 23 | 17 | 24 | 50 | 123 | 61 | 17 | 16 |
| 1873 | 30 | 46 | 29 | 19 | 27 | 108 | 69 | 20 | 17 |
| 1874 | 37 | 36 | 29 | 23 | 30 | 104 | 80 | 21 | 5 |
| 1875 | 42 | 54 | 38 | 26 | 39 | 100 | 51 | 14 | 1 |
| 1876 | 45 | 40 | 40 | 35 | 41 | 94 | 55 | 16 | 0 |
| 1877 | 36 | 30 | 25 | 18 | 46 | 113 | 69 | 25 | 3 |
| 1878 | 48 | 36 | 37 | 20 | 32 | 94 | 63 | 28 | 7 |
| 1879 | 39 | 50 | 41 | 21 | 43 | 105 | 39 | 16 | 11 |
| 1880 | 38 | 65 | 34 | 16 | 37 | 106 | 42 | 15 | 13 |
| 1881 | 39 | 49 | 34 | 25 | 41 | 107 | 38 | 22 | 10 |
| 1882 | 26 | 35 | 25 | 28 | 46 | 127 | 41 | 22 | 15 |
| 1883 | 41 | 37 | 26 | 30 | 41 | 115 | 40 | 27 | 8 |
| 1884 | 40 | 42 | 38 | 25 | 41 | 103 | 49 | 18 | 10 |
| 1885 | 44 | 55 | 35 | 30 | 39 | 107 | 30 | 20 | 5 |

Again, on the average of 25 years, 1859 to 1883, Mr. Prince finds for Crowborough, North-east 63 days, South-west 99 days. The corresponding Greenwich values are 48 and 111.

NUMBER OF DAYS OF PREVALENCE OF DIFFERENT WINDS IN EACH YEAR 1841 TO 1889, AS DERIVED FROM THE RECORDS OF THE SELF-REGISTERING OSLER ANEMOMETER OF THE ROYAL OBSERVATORY, GREENWICH.—*Continued.*

| Year. | N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|---|
| 1886 | 42 | 49 | 44 | 20 | 40 | 97 | 45 | 16 | 12 |
| 1887 | 58 | 62 | 34 | 17 | 30 | 94 | 40 | 21 | 9 |
| 1888 | 49 | 49 | 33 | 24 | 39 | 105 | 41 | 18 | 8 |
| 1889 | 51 | 44 | 28 | 24 | 40 | 96 | 45 | 20 | 17 |
| Means 1841-1864. | 39 | 46 | 23 | 21 | 32 | 107 | 41 | 24 | 32 |
| Means 1865-1889. | 40 | 44 | 31 | 23 | 37 | 106 | 50 | 21 | 13 |
| Means 1841-1889. | 40 | 45 | 27 | 22 | 35 | 106 | 46 | 22 | 22 |

Mr. Prince gives the average frequency of different winds 1885 to 1889. From the accompanying Table I have prepared corresponding numbers for Greenwich. We thus have :—

Mean prevalence of different winds, 1885 to 1889.

AT CROWBOROUGH.

| N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|
| 41 | 102 | 21 | 22 | 38 | 72 | 50 | 17 | ... |

AT GREENWICH.

| N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|
| 49 | 52 | 35 | 23 | 37 | 100 | 40 | 19 | 10 |

Mr. Prince further gives averages of 47 years, which he has since informed me are for the years 1843 to 1889, as follows :—

| N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|
| 33 | 63 | 29 | 27 | 28 | 91 | 59 | 35 | ... |

The Greenwich values for the corresponding 47 years from the annexed Table, are :—

| N. | NE. | E. | SE. | S. | SW. | W. | NW. | Calm. |
|---|---|---|---|---|---|---|---|---|
| 39 | 46 | 27 | 23 | 34 | 106 | 46 | 22 | 22 |

For the individual years, 1885 to 1889, the comparison as regards North-east and South-west winds is as follows :—

| Year. | | Crowborough. | | Greenwich. | |
|---|---|---|---|---|---|
| | | NE. | SW. | NE. | SW. |
| 1885 | ... | 98 | 74 | 55 | 107 |
| 1886 | ... | 102 | 83 | 49 | 97 |
| 1887 | ... | 128 | 67 | 62 | 94 |
| 1888 | ... | 95 | 71 | 49 | 105 |
| 1889 | ... | 88 | 65 | 44 | 96 |
| Means | ... | 102 | 72 | 52 | 100 |

Thus the results for the two places are entirely at variance in late years in a way that has not previously been experienced in such persistent fashion. It would be now interesting to make comparison, if possible, with similar statistics derived from observations made at some southern station nearer to Crowborough.

## DISCUSSION.

The PRESIDENT (Mr. Latham) said that he always preferred to ascertain the direction of the wind from the motion of low clouds or smoke. He did not trust to vanes, as they so frequently got fixed; and probably some of the differences shown in the paper might be due to errors in the vanes.

Mr. SYMONS read the following letter from Mr. Prince, of Crowborough Beacon:—

"Dear Mr. Symons,—As I find that I shall not be able to attend the Meeting of the Royal Meteorological Society on the 16th instant, I send you records as to the prevalence of North-east and South-west winds at Forest Lodge, Maresfield, and Crowborough respectively, the former from data kindly supplied to me by Capt. Noble, F.R.A.S.

"The vane at Forest Lodge is about 230 feet and mine 850 feet above sea-level. The observations were made at both stations at 9 a.m. Forest Lodge is situated nearly five miles in a south-west direction from Crowborough.

| Years. | Crowborough. | | Forest Lodge. | | | Greenwich. | |
|---|---|---|---|---|---|---|---|
| | NE. | SW. | NE. | SW. | Blank Days. | NE. | SW. |
| 1885 | 98 | 74 | 77 | 71 | 51 | 55 | 107 |
| 1886 | 102 | 83 | 88 | 80 | 23 | 49 | 97 |
| 1887 | 128 | 67 | 120 | 71 | 33 | 62 | 94 |
| 1888 | 95 | 71 | 73 | 89 | 72 | 49 | 105 |
| 1889 | 88 | 65 | 96 | 78 | 37 | 44 | 96 |
| Mean .... | 102 | 72 | 90 | 75 | 43 | 52 | 100 |

"It will be seen by examination of the above table that the records kept at Forest Lodge are not complete, through absence of the observer, but by inserting corrections to the particular blank days taken from my own Journal at Crowborough we arrive at results given in the following table;—

| | Crowborough. | | Forest Lodge. | | Greenwich. | |
|---|---|---|---|---|---|---|
| | NE. | SW. | NE. | SW. | NE. | SW. |
| Mean as above......... | 102 | 72 | 90 | 75 | 52 | 100 |
| The Mean + correction applied for 216 blank days at Forest Lodge...... | ... | ... | 18 | 6 | ... | ... |
| | 102 | 72 | 108 | 81 | 52 | 100 |

"The application of this correction shows that the net reduced results at both places are practically the same.—Yours faithfully, C. LEESON PRINCE."

Mr. SYMONS said that he did not think that Mr. Prince's vane was open to the charge of being fixed or stuck. He then described the position of the vane and the method by which its indications were read, and showed how he had thought that it was possible the vane may have become affected by a lofty addition to Mr. Prince's house. It did not, however, appear that such was the case, as the observations made by Capt. Noble at Maresfield, about five miles distant from Crowborough, confirmed Mr. Prince's results. A vane fixed to a pole or mast often gave very unreliable observations. He had had a vane so fixed in his own garden, and had found that in dry weather the pole cracked and gradually

twisted round until the cardinal points had moved as much as 40° from their true position. When damp weather set in the pole twisted back to its proper position.

Mr. C. HARDING said that he had compared the wind observations obtained by the Meteorological Office for 8 a.m. each day at London, Dungeness and Hurst Castle for the five years 1885 to 1889, and had found the number of days of North-east and South-west winds to be as follows:—

| Years. | London. | | Dungeness. | | Hurst Castle. | |
|---|---|---|---|---|---|---|
| | NE. | SW. | NE. | SW. | NE. | SW. |
| 1885 | 42 | 69 | 38 | 56 | 72 | 63 |
| 1886 | 41 | 62 | 41 | 46 | 78 | 67 |
| 1887 | 58 | 53 | 65 | 45 | 92 | 51 |
| 1888 | 51 | 65 | 41 | 65 | 72 | 75 |
| 1889 | 48 | 60 | 40 | 56 | 73 | 56 |
| Mean for 5 years .... | 48 | 62 | 45 | 54 | 77 | 52 |

Considering the mean result for the five years 1885-9, and taking the North-east winds as unity, the respective results are—

| | NE. | SW. |
|---|---|---|
| Crowborough ... ... ... ... | 1 | 0·7 |
| Greenwich... ... ... ... ... | 1 | 1·2 |
| London ... ... ... ... ... | 1 | 1·8 |
| Dungeness ... ... ... ... | 1 | 1·2 |
| Hurst Castle ... ... ... ... | 1 | 0·7 |

He could not say whether the last few years had been exceptional with respect to the prevalence of North-east winds, but it was noteworthy that recent years have been marked by an absence of great storms so far as the British Islands are concerned, and more especially over the South of England.

Mr. ELLIS said, regarding the question of periodical variations of the wind, that he did not himself attach much importance to such periodicities as were pointed out by Mr. McDowall (see next paper), considering them to be more of accidental character, rather than as indicating recurring phenomena. On the question of the sticking of vanes he might, perhaps, mention an experiment which he once made with the Greenwich Osler vane, as showing the delicacy of its action. It may be premised that a collar on the vane shaft bears upon anti-friction rollers, running in a cup of oil, rendering the vane very sensitive to changes of direction in light winds. On the occasion in question the Robinson cups were turning at the rate of about four revolutions per minute, indicating a very low velocity. The Osler vane was pointing South-by-west. It was turned by hand to East, but, when released, slowly came back to South-by-west. It was then turned to West, and similarly came back nearly to South-by-west. Other trials have been made with similar results.

# ON SOME RECENT VARIATIONS OF WIND AT GREENWICH.

By ALEX. B. MACDOWALL.

[Received April 29th—Read June 18th, 1890.]

AMONG the tabular statements issued from the Royal Observatory, Greenwich, is one which shows the relative proportion of wind each year reduced to the four cardinal directions. These four numerical series present some interesting features of variation,—the nature of which appears to call for more elucidation than it has yet received.

In the accompanying diagram are given (lower part) two curves showing the variations in Easterly and Southerly wind during the last 30 years (1860-89). The horizontal dotted line indicates the average of Easterly wind during the period (69·9 days).

In studying these and the other data, we are led to note the following points:—

(1.) The proportion of Easterly winds has been in general increasing. Observe the general rise in the curve and its successive maxima; traversing at times within the last ten years the curve of Southerly winds.

In the first 15 years, the sum of the days is 962; in the second it is 1185. Grouping the years in fives, we have the following sums:—

317, 301, 344, 364, 367, 404.

(2.) The fluctuations in the proportion of Easterly winds tend to widen. Thus, if we compare the intervals between minima and their following maxima, we have the series:—

22, 29, 30, 44, 49.

(3.) The recurrence both of minima and maxima presents a certain regularity. We find minima in 1863, 1867, 1872, 1877, 1882, and 1888, giving the series of intervals

4, 5, 5, 5, 6 years.

Relative maxima are found in 1861, 1864, 1871, 1875, 1880, and 1885; giving the series of intervals

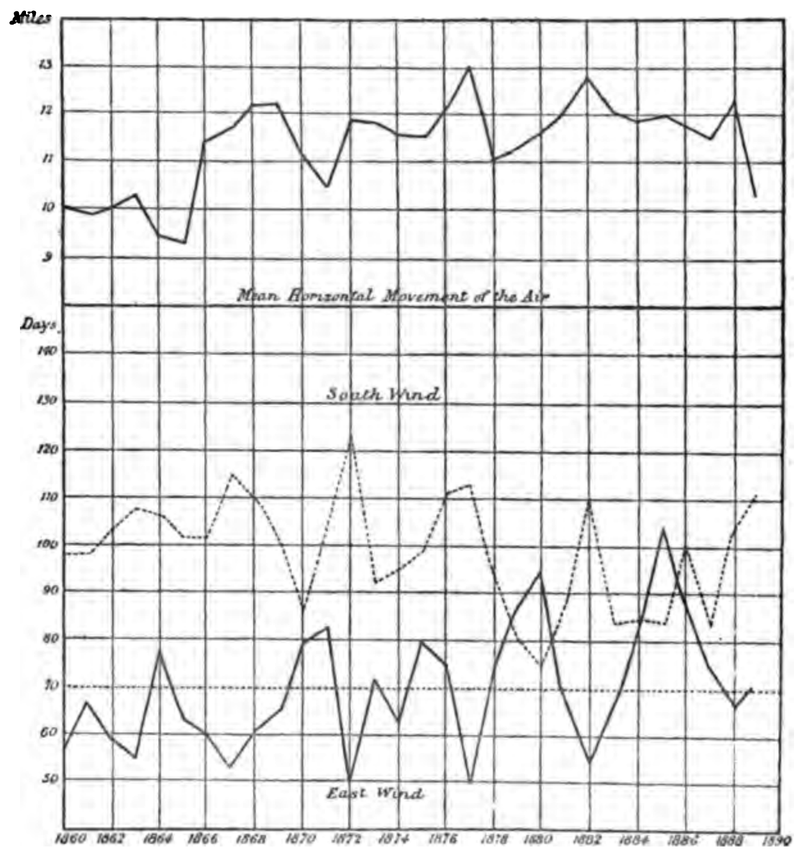
3, 7, 4, 5, 5 years,

which is evidently less regular.

(4.) To the minima of Easterly wind generally correspond maxima of Southerly wind, and to some extent maxima of Easterly wind are found with minima of Southerly wind. Thus the curve of Southerly wind presents more or less regular recurrences; the intervals between the maxima are 4, 5, 5, 5, &c. The series of minima is rather irregular.

The most noteworthy features of the two remaining curves, for Northerly and Westerly winds respectively (which seem very irregular, and are not here given), are perhaps these :—

(5.) There is a general rapid rise in the proportion of Northerly wind from an absolute minimum in 1882 to an absolute maximum in 1887 ; and there is a continuous fall in the curve of Westerly winds from an absolute maximum in 1883 to the lowest point yet reached (in those 30 years), in 1889.




Variations of Wind at Greenwich.

The numbers are as follows :—

| | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. | 1888. | 1889. |
|---|---|---|---|---|---|---|---|---|
| North. | 48 | 60 | 76 | 64 | 67 | 100 | 90 | 93 |
| West. | | 151 | 123 | 114 | 110 | 108 | 106 | 90 |

The maxima of Southerly wind correspond sometimes with a high point, sometimes with a low one, in either of the curves of Northerly and Westerly wind.

Comparing a curve of mean horizontal movement of the air at Greenwich (see diagram, upper part) we find that

(6.) The minima of Easterly winds and maxima of Southerly winds generally correspond with relative maxima in the curve of horizontal movement. (It is known that Easterly winds have the least average intensity of all winds; being weaker than Northerly, these again than Southerly, and these than Westerly.) We have then in this horizontal movement curve another case of recurrence, finding relative maxima at the following intervals :—

5, 4, 5, 5, 6 years.

(7.) There is apparently a similar recurrence in severe winters (in recent years). Comparing the winters of those 30 years in respect of severity, we find relative maxima (of severity) in the following years: 1864-65, 1869-70 (interval 5 years), 1874-75 (5 years), 1879-80 (5 years), 1885-86 (6 years). These winters correspond pretty nearly, it will be seen, with the maxima of Easterly wind.

A proximate explanation of this recurrence of about 5 years would, no doubt, appear from a comprehensive survey of the conditions of barometric pressure obtaining throughout those 30 years. But the causes of relative displacement of those barometric maxima and minima, from time to time (producing wind variations), are still in the main a *terra incognita* for meteorology.

Do these data, it may be asked, afford any ground for prediction? One can only say, that should this recurrence (say) in the curve of Easterly wind be continued, we should rather expect, having passed a minimum, apparently in 1888, to have, during this year (1890) and next, increasing proportions of Easterly wind. On the other hand, the high position now reached by the curve for Northerly winds, and the very low position of that for Westerly winds, would lead us to expect an early fall in the former and rise in the latter. And a study of winters with regard to relative severity, appears to suggest, that next winter will be still milder than its mild predecessor. But knowing how certain the unexpected is in meteorology, I shall not venture further on dangerous ground.

# ON THE ACTION of LIGHTNING DURING THE THUNDERSTORMS of JUNE 6th & 7th, 1889, AT CRANLEIGH, SURREY.

By Capt. J. P. MACLEAR, R.N., F.R.Met.Soc., F.R.G.S.

[Received June 7th—Read June 18th, 1890.]

During the thunderstorms of June 6th and 7th, 1889, so many trees were struck within a radius of 4 miles from Cranleigh, that I set to work to discover, if possible, the cause of selection of these particular trees; for, contrary to general expectation, they were not the highest nor the most prominent in their immediate vicinity; and though I cannot say I have solved the question, as the causes of preference appear to be very slight, yet I think I can put forward some interesting facts which may help us to a further knowledge of the nature of the electric discharge, and the course it may be likely to follow.

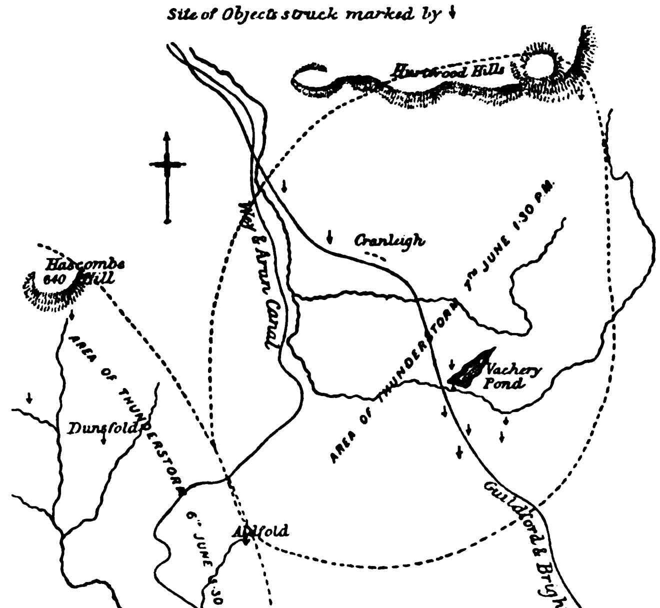
On June 6th, the storm first appeared to the southward of Cranleigh, about 4.43 p.m., and it passed about 4 miles to the South-west. About 5.30 p.m., shortly before rain commenced, the following objects were struck, apparently about the same time, but, as no accurate observations were made as to time, it cannot be determined whether one or several discharges were concerned. On Dunsfold Common, 4 miles South-west of Cranleigh, a cottage was struck, a chimney at the south-east end knocked down, and the register grates on two floors started from their places; a haystack about 100 yards south of the cottage was set on fire, and two poplars 300 yards west of the cottage were struck, each tree having a score down it, 1½ inches width of bark being stripped off. On Hascombe Hill, 1¼ miles north of the cottage, and 400 feet above its level, a spruce fir was shivered; at Alfold, 1¾ miles south-east of the cottage, two oaks were struck, one was only scored but the other was split (this latter tree was struck again and splintered the next day); also three oaks about a mile to the westward of the cottage were struck, but as it is only conjecture that they were struck at the same time I shall not refer to them again. More trees may have been struck in the neighbourhood but not noticed.

As for the causes of these objects being selected, it will be seen that they lie nearly in a line North-west and South-east 3 miles in length. Mr. Marriott has shown (*Quarterly Journal*, No. XV. p. 222) that the storm was passing in a north-west direction with a South-east wind; it is possible that the storm was delayed by the high Hascombe hills and the charged cloud thereby concentrated. The spruce fir was very prominent on the southern brow of the hill; it divided into two arms nearly in line with the stem; one arm

was thrown to the ground, the other blown down by the wind a few hours afterwards. At the junction of the arms there was a great deal of turpentine, which was thoroughly blackened. In this case I should consider that the prominence of the tree made it the best communication to earth, and that the collection of turpentine at the juncture of the arms was raised to explosive temperature and split the tree.

The cottage, haystack and two poplars on Dunsfold Common do not immediately suggest a cause of selection, but from their position the ground falls to the south-east in a wooded valley through which the Arun and Wey canal runs, and on the other side of this wooded valley are the Alfold trees. Streams into the canal run from near all the objects struck, and though I hesitate to advance this point, it is possible that the earth electricity was thus able to collect more readily at these places than at others under the cloud. It would be exceedingly interesting to know if these three objects were all struck by the same discharge.

SKETCH OF THUNDERSTORM AREA OF JUNE 6TH & 7TH 1889.
*Site of Objects struck marked by ↓*




On June 7th, the storm began with little warning at 1.10 p.m., and was at its height at 1.27, when there fell the heaviest rain known to the oldest inhabitant. About 1.30 p.m. the following objects were struck:—Near Vachery pond, a large reservoir for the Arun and Wey canal 1¼ mile south-east of Cranleigh, six oaks, a chestnut, and an ash, in various positions within

½ mile of the pond and about ¼ of a mile apart, a young fir and three young oaks in the middle of a copse on the slope of the ground near the pond, four oaks ½ a mile south of Cranleigh, one oak on Cranleigh Common, a chimney and stable 1 mile north-west of Cranleigh, besides the oak tree before mentioned at Alfold, and a single oak occupying a fairly prominent position on the slope of the high hills 2½ miles to the north-east of Cranleigh. This last tree was struck just before the rain commenced on the hill, and was split; the other trees struck, during the rain, were only scored.

Here the area of discharge extends along a line about three miles in length North-west and South-east, as on the previous day; and with the exception of the Alfold tree before referred to 3 miles to the south-west, and the tree on the hill 3 miles north-east, all the objects struck were scattered along the line of railway, and at no great distance from it.

It is not easy to see the cause of selection, for these trees were not the most prominent nor were they on the highest ground in the vicinity; the only feature the groups possessed in common being that they were all either near ditches which were full of running water, or else near temporary courses taken by the deluge of water from the higher to the lower ground. The most puzzling case is that of the young fir tree and three young oaks in the middle of the copse near Vachery pond; they were not higher than the other trees in the copse, but there certainly was a temporary water course running close to them; other trees, however, stood equally close to the water, and unless a large squirrel's nest of moss on the top of the young fir be called upon to account for the selection, it still remains obscure. Another curious case is that of the stable struck, which was overshadowed by tall elms, where it might have been supposed that these would have taken the stroke.

Of the species of trees struck, the oak is the most frequent, and I am inclined to believe that the reason is not that there are more oaks than other trees in the neighbourhood, but that the roughness of the bark causes gaps of its continuity as a conductor; elms, firs, poplars and chestnuts have been struck, but it is said that the beech is never struck.[1] It has been said, also, that oaks are more frequently struck in the spring and other trees in the autumn, but this requires confirmation.

The injuries to the trees are of two kinds: the first, by far the most common, is simply a score out of the bark up the trunk of the tree, out along one limb, and then by perhaps two or three branches to the outer twigs; in some cases portions of the bark are blown off as well. A very good illustration of this effect is found in a paper by the Rev. O. P. Cambridge, *On the effect of a flash of lightning at Bloxworth, April 9th, 1886.*[2] In these cases I imagine that the rain is falling, and one or more streams of water are running down the sides of the tree, forming a conductor which becomes insufficient, at the time of discharge, to carry off all the electricity, and

[1] *The Action of Lightning.* By Col. Parnell, p. 27.
[2] This paper is in the Library of the Royal Meteorological Society.

therefore becomes so suddenly converted into steam as to blow out the bark along the line, and if there is communication with the sap by a knot, hole, or other flaw, the sap is also converted into steam and the bark blown off.

The other form is the shattering of the tree, which I imagine to occur when the electricity is insufficiently carried off by the outer surface, and collects at the junction of some main branch with either the stem or with some other branch, where there is perhaps a cavity with water in it, or a collection of moist dead leaves; the tree is then easily rent by the explosion of steam generated. If the tension be very great, and especially if the air round the tree be dry, the sap may be violently exploded, and the trunk splintered and shattered as if by dynamite.

Of the trees which I have examined here, the only ones shattered were those struck before the rain fell; the others were scored simply, with bark blown off.

In the case of the stable struck on June 7th, I can only think that the electricity collecting at the top of the overhanging elm tree found a better conductor than the trunk in the hot moist air escaping from the near gable of the stable, and the hot air expanding blew the corner tile off to find a better vent. As to the cottage on Dunsfold Common struck on June 6th, I can trace no cause for selection; the appearance of the chimneys suggests an explosion of air.

As the result of my examinations I can only say that the causes of selection of objects struck appear too slight to be readily perceptible, or to enable one to say beforehand that such and such an object will probably be struck. It seems that during rain every tree is conducting electricity, and a disruptive discharge takes place where the conductor becomes insufficient. This would depend on the position of the cloud, the amount of foliage on the tree, its condition of moisture, and its connection with running water. Also I may point out, as shown by Prof. O. J. Lodge, that if an upper cloud should discharge to a lower one, the lower one may then discharge to earth violently without regard to any conductors.

It would be desirable if those who have the opportunity of observing objects immediately after they are struck would note the surrounding conditions and proximity to water, and whether, in the case of trees struck during rain, the score is on the side on which the rain beats.

# PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

MAY 21ST, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

WILLIAM FRIESE GREENE, 92 Piccadilly, W.; and
FRANCIS HOLMES PHILLIPS, 1 Prestonville Road, Brighton,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"RAINFALL OF THE GLOBE.—COMPARATIVE CHRONOLOGICAL ACCOUNT OF SOME OF THE PRINCIPAL RECORDS." By W. B. TRIPP, M.Inst.C.E., F.R.Met.Soc. (p. 193.)

"MUTUAL INFLUENCE OF TWO PRESSURE PLATES UPON EACH OTHER, AND COMPARISON OF THE PRESSURES UPON SMALL AND LARGE PLATES." By W. H. DINES, B.A., F.R.Met.Soc. (p. 205.)

"ON THE VARIATIONS OF PRESSURE CAUSED BY THE WIND BLOWING ACROSS THE MOUTH OF A TUBE." By W. H. DINES, B.A., F.R.Met.Soc. (p. 208.)

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JUNE 18TH, 1890.

Ordinary Meeting.

BALDWIN LATHAM, M.Inst.C.E., President, in the Chair.

CLINTON COLERIDGE FARR, B.Sc., St. Luke's Parsonage, Whitmore Square Adelaide;
JOSEPH HALL, Assoc.M.Inst.C.E., Town Hall, Torquay;
CHARLES ROBERT RIVINGTON, 74 Elm Park Gardens, S.W.; and
JOHN LIVESAY WHITEHEAD, M.D., Belgrave House, Ventnor, Isle of Wight,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"ON THE DIFFERENCE PRODUCED IN THE MEAN TEMPERATURE DERIVED FROM DAILY MAXIMUM AND MINIMUM READINGS, AS DEPENDING ON THE TIME AT WHICH THE THERMOMETERS ARE READ." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 213.)

"ON THE DISTRIBUTION OF BAROMETRIC PRESSURE AT THE AVERAGE LEVEL OF THE HILL STATIONS IN INDIA, AND ITS PROBABLE EFFECT ON THE RAINFALL OF THE COLD WEATHER." By W. L. DALLAS. (p. 220.)

"ON THE RELATIVE PREVALENCE OF DIFFERENT WINDS AT THE ROYAL OBSERVATORY, GREENWICH, 1819-1889." By WILLIAM ELLIS, F.R.A.S., F.R.Met.Soc. (p. 221.)

"ON SOME RECENT VARIATIONS OF WIND AT GREENWICH." By A. B. MACDOWALL. (p. 226.)

"ON THE ACTION OF LIGHTNING DURING THE THUNDERSTORMS OF JUNE 6TH AND 7th, 1889, AT CRANLEIGH, SURREY." By Capt. J. P. MACLEAR, R.N., F.R.G.S., F.R.Met.Soc. (p. 229.)

# CORRESPONDENCE AND NOTES.

## Conditions of Tornado Development.

Lieut. J. P. Finley, U.S.A., in his Prize Essay on "Tornadoes,"[1] gives the following as the conditions under which Tornadoes are formed:—

Tornadoes form in connection with cyclonic areas of low pressure, to which they bear certain relations that can be defined.

Not all low pressure areas develop the conditions necessary for tornado formation, which are:—1st. Unstable equilibrium; 2nd. A gyratory motion of the air relative to some centre of circulation. The second condition is always present, to a greater or less degree, in every cyclone, but the combination of the two, the *sine quâ non* of tornadic development, fortunately, for some very good reasons, occurs with much less frequency.

There is good reason for the opinion that a certain form of the area of low pressure (trough-like, trending north and south, or north-east and south-west) is more conducive to tornado conditions than any other. Such a form of depression brings in closer proximity the opposing conditions of heat and moisture of the north-west and south-east quadrants of the low, which state of things is especially favourable to the development of unstable equilibrium (the most important factor in tornado generation) in the South-east quadrant.

It is now no longer a moot question that tornadoes form in a certain quadrant (the south-east) of the low area which they attend.

The reason for this is found in the fact that this quadrant is the great heat and moisture region of the low, and where the circulation of the warm moist air, underneath the cold, anticyclonic air currents from the North, gives rise to the development of unstable equilibrium.

Not only is the South-east quadrant the tornadic region of the low, but it is also the region which gives birth to all violent local storms. All such disturbances depend upon unstable equilibrium as an initiatory force.

The results of the study of tornado maps may be briefly summarised as follows:—

1. That the tornado region is not coincident with area of lowest pressure.
2. The tornado region is confined to the south-east quadrant of the low.
3. The tornado region is several hundred miles south-eastward from the general storm centre.
4. The south-east quadrant is the region of greatest heat and moisture in the low. As to moisture, the North-east quadrant is also prominent.
5. The south-east quadrant is the local storm region of the low.
6. The local storm region is within the belt of Southerly winds.
7. The line of separation between Northerly and Southerly winds approximately marks the limit of precipitation to the east and west.
8. The area of precipitation moves eastward with this line.
9. That along this line, on both sides of it, the heaviest precipitation generally occurs, and also some of the heaviest winds.
10. The average wind velocity is generally highest in the south-west and north-west quadrants, followed next in order by the south-east quadrant.
11. The highest wind velocities (25 miles per hour and upward) occur in the south-west quadrant, where they are also the most frequent.
12. The south-east quadrant stands next in order to the south-west for maximum wind velocities, both in number and degree.
13. The north-west quadrant stands third in order, followed by the north-east quadrant with no maximum velocities.
14. The maximum velocities are principally confined to the latter half of the day, especially in the south-east quadrant.
15. As the low approaches the meridian of the tornado region the Southerly winds gradually increase in velocity, the isotherms curve more to the north, the moisture increases and the dew-point rises.
16. In the morning the highest wind velocities in the south-east quadrant are near the centre of the low, and during the afternoon and evening, near the centre of the tornado region. [*Continued on* p. 286.]

[1] *American Meteorological Journal.* Vol. VII. p. 166.

## RAINFALL IN CHINA IN 1889. By William Doberck, Ph.D., F.R.Met.Soc., Government Astronomer, Hongkong.

| Station. | Lat. N. | | Long. E. Greenwich. | | Jan. | Feb. | Mar. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Year. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ° | ′ | ° | ′ | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. | In. |
| Yuensan | 39 | 9 | 127 | 33 | 1·67 | ·83 | 2·57 | ·08 | 2·50 | 5·79 | 7·51 | 7·08 | 2·65 | 2·74 | 1·09 | .. | 34·51 |
| Houki | 38 | 4 | 120 | 39 | .. | .. | .. | .. | .. | 1·94 | 7·05 | 1·82 | 1·30 | 1·20 | .. | ·30 | 13·61 |
| Chefoo | 37 | 34 | 121 | 32 | .. | ·05 | ·47 | ·32 | ·15 | 1·99 | 11·14 | 4·81 | 3·15 | 1·66 | 1·72 | .. | 25·46 |
| Chemulpo | 37 | 29 | 126 | 37 | ·92 | ·49 | ·69 | 1·62 | 1·91 | 4·87 | 10·10 | 1·18 | 2·33 | 2·70 | 3·04 | ·18 | 30·03 |
| Shangtung Promontory | 37 | 24 | 122 | 42 | .. | .. | ·58 | ·50 | ·83 | 1·42 | 6·48 | 2·58 | 3·98 | ·55 | 1·46 | .. | 18·38 |
| Fusan | 35 | 5 | 129 | 6 | 2·25 | ·48 | 1·93 | 3·88 | 5·62 | 16·74 | 14·66 | 6·86 | 2·22 | ·62 | 1·20 | 1·14 | 57·60 |
| Chinkiang | 32 | 12 | 119 | 30 | ·58 | 1·78 | ·79 | 2·72 | 2·21 | 19·98 | 5·07 | 3·72 | 4·92 | 7·21 | 1·00 | .. | 49·98 |
| Shaweishan | 31 | 25 | 122 | 15 | 1·04 | 2·67 | 4·07 | 3·13 | 2·66 | 9·02 | 8·49 | 3·45 | 3·09 | 10·07 | 1·74 | ·24 | 49·67 |
| Wuhu | 31 | 22 | 118 | 22 | 2·80 | 2·79 | 4·31 | 3·67 | 3·72 | 11·12 | 3·59 | 1·33 | 8·05 | 8·35 | 2·27 | ·05 | 52·05 |
| North Saddle | 30 | 52 | 122 | 40 | 1·67 | 2·66 | 2·60 | ·52 | 1·84 | 4·93 | 3·39 | 2·65 | 3·51 | 6·93 | 1·60 | ·54 | 32·84 |
| Hankow | 30 | 33 | 114 | 20 | 1·49 | 3·06 | 4·90 | 6·66 | 9·17 | 23·51 | 6·25 | 3·08 | 12·39 | 9·04 | 2·42 | ·05 | 82·02 |
| Ichang | 30 | 12 | 111 | 19 | ·62 | 1·91 | ·74 | 4·56 | 5·20 | 8·77 | 5·93 | 14·93 | 9·82 | 5·13 | 1·05 | ·12 | 58·78 |
| Steep Island | 30 | 12 | 122 | 36 | 1·69 | 3·44 | 4·40 | 3·77 | 2·42 | 2·82 | ·98 | 2·16 | 3·39 | 6·67 | 1·92 | ·12 | 33·78 |
| Ningpo | 29 | 58 | 121 | 44 | 7·65 | 5·18 | 4·51 | 5·32 | 4·05 | 6·86 | 9·80 | 18·65 | 6·43 | 13·75 | 3·07 | ·52 | 85·79 |
| Kinkiang | 29 | 43 | 116 | 7 | 3·87 | 4·04 | 2·12 | 7·92 | 9·78 | 7·61 | 6·25 | 3·52 | 7·71 | 8·89 | 3·85 | ·25 | 65·81 |
| Wenchow | 28 | 0 | 120 | 35 | 2·59 | 3·99 | 3·84 | 10·53 | 10·66 | 8·43 | 6·14 | 12·96 | 1·52 | 6·76 | 1·97 | 1·55 | 70·94 |
| Foochow | 26 | 8 | 119 | 38 | 1·68 | 2·31 | 6·86 | 5·41 | 5·18 | 1·87 | 1·20 | 5·97 | ·61 | 6·20 | 5·82 | 1·20 | 44·31 |
| Middle Dog | 25 | 58 | 120 | 2 | 1·08 | 1·91 | 5·96 | 5·60 | 4·10 | 1·56 | .. | ·48 | 1·22 | 5·50 | ·77 | ·78 | 28·96 |
| Tam Sui, Formosa | 25 | 10 | 121 | 25 | 7·22 | 5·23 | 7·28 | 11·63 | 6·97 | 8·78 | ·64 | 8·40 | ·10 | 4·33 | 9·64 | 2·52 | 72·74 |
| Keelung, Formosa | 25 | 8 | 121 | 45 | 27·69 | 13·73 | 11·45 | 10·85 | 6·69 | 8·26 | 1·87 | 6·22 | 2·55 | 25·29 | 17·25 | 11·66 | 143·51 |
| Ockseu | 24 | 59 | 119 | 28 | 1·05 | 1·75 | 3·38 | 5·40 | 4·89 | 2·50 | 3·67 | 1·38 | .. | ·57 | ·35 | ·20 | 25·14 |
| Amoy | 24 | 27 | 118 | 4 | 1·79 | 3·60 | 3·29 | 3·50 | 5·69 | 7·58 | 6·28 | 2·95 | ·41 | 4·02 | 2·05 | 1·30 | 42·46 |
| Chapel Island | 24 | 10 | 118 | 13 | 1·13 | 1·36 | 2·29 | 6·00 | 6·96 | 3·51 | 1·98 | 1·47 | ·42 | 3·64 | 3·40 | ·02 | 32·18 |
| Fisher Island | 23 | 33 | 119 | 28 | ·58 | ·58 | ·63 | 2·65 | 12·08 | 15·14 | 3·13 | 5·07 | ·60 | 2·78 | ·69 | .. | 43·93 |
| Swatow | 23 | 20 | 116 | 43 | 2·06 | 1·60 | 2·62 | 3·89 | 16·31 | 10·67 | 10·23 | 8·91 | 2·23 | 2·60 | 2·37 | ·08 | 63·57 |
| Lamocks | 23 | 15 | 117 | 18 | ·76 | ·96 | 2·90 | 2·30 | 17·67 | 14·31 | 1·75 | 1·62 | ·43 | 3·63 | ·82 | .. | 47·15 |
| Canton | 23 | 7 | 113 | 17 | ·67 | ·98 | 3·37 | 6·99 | 17·67 | 7·47 | 2·83 | 9·23 | 3·15 | 5·51 | ·87 | ·18 | 58·92 |
| Anping | 22 | 59 | 120 | 13 | ·69 | ·28 | 2·97 | 7·05 | 19·40 | 18·70 | 20·43 | 13·02 | 1·74 | ·71 | .. | .. | 84·99 |
| Breaker Point | 22 | 56 | 116 | 28 | ·94 | 1·77 | 3·53 | 5·66 | 20·73 | 20·74 | 1·50 | 5·41 | 1·10 | 5·73 | ·46 | ·03 | 67·60 |
| Takow | 22 | 36 | 120 | 16 | ·49 | ·08 | ·78 | 8·00 | 11·75 | 16·41 | 8·21 | 13·50 | 1·70 | 4·52 | ·19 | ·03 | 65·66 |
| Hongkong | 22 | 18 | 114 | 10 | ·73 | ·72 | 2·49 | 12·27 | 48·84 | 9·71 | 4·58 | 18·14 | 11·80 | 8·72 | 1·54 | ·17 | 119·71 |
| South Cape, Formosa | 21 | 55 | 120 | 51 | 2·03 | ·69 | 1·98 | 2·68 | 5·79 | 13·25 | 7·09 | 20·89 | 3·16 | 27·96 | 3·89 | 1·45 | 90·86 |
| Pakhoi | 21 | 29 | 109 | 6 | 1·10 | ·56 | 3·10 | 2·58 | 3·19 | 3·34 | 6·60 | 30·35 | 12·48 | 1·10 | 2·85 | ·22 | 67·47 |
| Kiung Chow, Hainan | 20 | 3 | 110 | 20 | ·26 | 1·66 | ·46 | 3·82 | 5·03 | 3·13 | 4·05 | 13·42 | 6·44 | 8·06 | 4·82 | ·53 | 51·68 |

17. In the south-west quadrant the highest wind velocities are most distant from the centre of the low in the morning, thereafter gradually drawing nearer, reaching the nearest point in the evening.

18. In the North-west quadrant the conditions are similar to those in the south-west quadrant, except that the highest velocities are near the centre of the low.

19. The wind velocities in the north-east are not particularly strong.

20. The wind velocities here referred to appear to have important connection with the tornado region, especially those occurring in the south-west and south-east quadrants.

21. The apex of the curve of high temperature is much nearer the centre of the low than the apex of the curve of low temperature.

22. The tornado region does not coincide with the region of the highest temperature gradient, as shown by the surface observations, but lies to the south and east of it several hundred miles, being nearest about noon, and most distant about sundown.

23. There are two regions of marked temperature gradient, the most decided lying between the northern portion of the South-east quadrant and the southern portion of the north-west quadrant, the other region lying between the northern portion of the south-west quadrant and the southern portion of the south-east quadrant.

24. The tornado region (in the particular case under consideration) lies nearest the southern temperature gradient region.

25. In some cases the tornado region lies about half-way between the two temperature gradient regions, and sometimes nearer the northern one, yet more frequently nearest the southern region.

26. As practically the whole of the south-east quadrant of the low is subject to unstable equilibrium, it is rather difficult to say just where the most decided conditions will manifest themselves. In this connection it must be borne in mind that all violent local storms result from unstable equilibrium, and that the hailstorm is a tornado above the surface of the ground.

27. As the unstable equilibrium which gives rise to a tornado appears to first manifest its force in the cloud region, where the whirl always starts, it is not strange that the surface observations frequently fail to show a direct connection therewith.

The tornado is there, and, with the aid of both local and telegraphic stations properly distributed, the weather chart may be able to furnish the desired information for prognostication.

Observations at considerable heights, from captive balloons, may prove very useful in this connection.

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## The Climate of Malta.

In a paper on "The Maltese Islands, with special reference to their geological structure," in the *Scottish Geographical Magazine* for September 1890, Dr. J. Murray gives the following account of the climate:—"The mean January temperature in Malta is 54°·5; the mean temperature of the three winter months (December, January, February) is 56°·0; the rainfall for the same months is 17°·5 ins., and during this time there are frequently hailstorms, but no snow. The mean annual temperature is 67°·3, and the annual rainfall 24·28 ins. During the eight cool months the thermometer only on rare occasions falls below 50°, and does not rise above 71° or 72°. In summer the heat is almost tropical, the temperature ranging between 75° and 90°, and there is little or no rain. For three successive years—from 1467 to 1470—no rain is said to have fallen at Malta, and the islands suffered greatly from drought. In 1852 only 8·27 ins. fell, and in 1866 only 10·49 ins. are recorded.

"The Northerly wind is bracing, and sometimes approaches the force of a gale.[1] In February 1889 this wind was so cold that in driving it was necessary to wear heavy fur coats and jackets; and at times the wind was accompanied with such heavy falls of hail that the ground became quite white for an hour or

[1] "Gregale," or Euroklydon.—Acts xxvii. 14.

two. The South-west wind—the Sirocco from the African deserts—is very enervating; though this is a dry wind in Africa, it is in Malta charged with vapour, and while it is blowing, the pavements of the streets are wet, and everything feels damp. There are no rivers nor marshes on the islands, but during heavy rains the valleys are filled with torrents. Springs are found at the junction of the upper limestone with the underlying beds of clay and marl. The rain is speedily absorbed by the porous rocks. Earthquakes are relatively frequent, and coincident with disturbances in the Eastern Archipelago."

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## RECENT PUBLICATIONS.

American Meteorological Journal.—A Monthly Review of Meteorology and Medical Climatology. July-September 1890. Vol. VII. Nos. 3-5. 8vo.

The principal original articles are:—Professor Elias Loomis; by Prof. H. A. Newton (20 pp. and portrait). This is a memorial address reprinted from the *American Journal of Science and Arts.*—State Tornado Charts; by Lieut. J. P. Finley (21 pp.). The States here dealt with are Florida, South Carolina, Minnesota, Mississippi, Kentucky, and Tennessee.—Trombes and Tornadoes; by H. Faye (21 pp.). This is a continuation of articles from the previous Nos. —Prize Essays on Tornadoes (65 pp.). The Editors and Publishers of the *American Meteorological Journal* some time ago offered prizes for the best essays on Tornadoes; and the August No. contains the prize essays in full. The first prize was awarded to Lieut. J. P. Finley, and the second to A. McAdie. There were two essays judged worthy of mention, between the authors of which the third prize has been equally divided, viz. Prof. H. A. Hazen, and J. M. Bennett. —A new recording rain and snow gauge; by S. P. Fergusson (2 pp.).—Espy's experiments on storm generation; by Prof. H. A. Hazen (4 pp.).—Origin of Storms; by E. B. Garriott (4 pp.).—Forests and Soil Temperatures; by M. W. Harrington (13 pp.).

British Rainfall, 1889.—On the Distribution of Rain over the British Isles during the year 1889, as observed at nearly 3,000 stations in Great Britain and Ireland, with Articles upon various branches of Rainfall work. Compiled by G. J. Symons, F.R.S. 1890. 8vo. 238 pp. and 5 plates.

This contains the particulars of the rainfall from 2,708 records. The rainfall for the year 1889 was about 8 per cent less than the average. In addition to the Observers' notes and other usual information, there is a long article (26 pp.) on the Amount of Evaporation. Mr. Symons gives an account of the experimental observations which were carried out at Strathfield Turgiss some years ago, and also describes the various evaporators used. The little tin vessels called evaporators were soon found to be utterly worthless, being so much affected by temperature. A galvanised iron tank, 6 feet square and 2 feet deep, and sunk in the ground so that the rim was 3 ins. above the grass, was found to give the best results, and regular observations have been made from this tank at Strathfield Turgiss from 1870 to 1883, and since then at Camden Square. The mean annual evaporation was: Strathfield Turgiss 1870-83 (14 years) 18·03 ins.; and Camden Square 1885-89 (5 years) 14·54 ins.

Cyclone Memoirs. Part II. Bay of Bengal Cyclone of August 21st-28th, 1888. Published by the Meteorological Department of the Government of India under the direction of J. Eliot, M.A., Meteorological Reporter to the Government of India, 1890. 8vo. 138 pp. and 18 plates.

This paper has been written by Mr. A. Pedler, Meteorological Reporter to the Government of Bengal. The storm was undoubtedly one of the class which usually forms during the rainy season in the Bay of Bengal, and not of the class

of the fierce cyclones which are generated at, what are called, the transitional periods, *i.e.* from April to the end of May, and from the middle of September to the beginning of November. But though it was of the feebler class of storms, called the cyclonic storms of the rains, the storm in question was in one quadrant at least of force almost equalling that which is usually experienced in the most destructive cyclones, and was of sufficient force to almost cause the loss of one, if not of two vessels. The storm was generated close to the land at the head of the Bay of Bengal, within a few miles of Saugor Island. This area has in its neighbourhood several meteorological observatories, and thus affords an excellent opportunity of watching the meteorological conditions which precede and accompany the formation of such a storm. The northern half of the storm after its formation was well over the land, and was of feeble character, as was also at first all the area near the centre of the storm, but in the southern half, which lay over the sea at a considerable distance from land, the cyclonic winds were extremely violent, and an attempt is made to account for the more remarkable distances in the wind-force in different parts of the storm which are here indicated. It is shown that at first the fierce part of the storm was confined to an area from about 90 to 200 miles to the south of the centre, but that as the storm passed inland the area of strong winds gradually closed up and came nearer and nearer to the centre. Another point of importance in the storm was the fact that the centre of the barometric depression was many miles to the south of the centre of the circulation of winds, which fact is perhaps connected with the distribution of the strength of the winds in the storm. The storm was also remarkable for the slight barometric depression which accompanied it when the excessive force of the winds is considered, and was very noticeable for the particularly heavy wave of rainfall which was brought up in its rear. Finally, there was another interesting feature in the storm, inasmuch as it was formed while there was a second, but smaller, storm already in existence, which had been for some days travelling across India in a westerly direction.

HAND-BOOK OF CYCLONIC STORMS IN THE BAY OF BENGAL. For the use of Sailors. By JOHN ELIOT, M.A., Meteorological Reporter to the Government of India. 1890. 8vo. 212 pp. and 29 plates.

The object of this volume is to give the mariner who navigates the Bay of Bengal an account of the dangerous storms that occur in it, to state and explain the signs and indications by which he may ascertain when he is approaching a cyclone, or that a cyclone is forming in that part of the Bay which he is traversing, and to furnish him with information and methods by which he may ascertain sufficiently for all practical purposes the bearing or direction of the storm-centre, and of the path of any cyclonic storm he may meet with in the Bay. The subject is treated under the following heads:—(1). Explanation of meteorological ideas and phrases and of some of the more important principles of the science; (2). Description of the chief phenomena of cyclonic storms in the Bay of Bengal, and explanation of methods of ascertaining the existence, position and course of cyclonic storms; (3). Brief account of six of the most important and typical storms in the Bay of Bengal during the past 25 years; and (4). Summary giving brief practical hints respecting storms for the use of sailors navigating the Bay of Bengal.

JOURNAL OF THE ASIATIC SOCIETY OF BENGAL. Vol. LIX., Part II., No. 1, 1890. 8vo.

Contains a paper by Mr. J. Eliot, entitled "On the occasional inversion of the temperature relations between the hills and plains of Northern India" (50 pp.). The paper really consists of three parts:—(1). A statement of the normal meteorological temperature conditions of the plain and hill districts of Upper India in the month of January, and of certain meteorological conditions and actions upon which temperature mainly depends; (2). A statement of the more striking abnormal relations of the month of January 1889 and of the cold weather period generally in Upper India; and (3). A discussion of the causes which produce these unusual conditions and temperature variations. The author shows that inversion may occur over very large plain areas, and that it has, in some cases at least, little or nothing whatever to do with air motion between hills and valleys. He

also shows that the vertical temperature relations during the cold weather in Northern India are much more variable and complicated than they have been hitherto supposed to be, and that the descensional motion which accompanies cooling of the air during the night in fine clear weather is almost entirely one of slow compression, and is not the opposite of the ascensional and convective movement which takes place largely during the day.

**Meteorological Observations made at Sanchez (Samaná Bay), St. Domingo, 1886-1888.** By the late W. Reid, M.D. Published by the Authority of the Meteorological Council. Official No. 89. 1890. 4to. 64 pp.

Samaná Bay is a large inlet at the eastern end of the island of St. Domingo. The observations were taken every two hours from 6 a.m. to 10 p.m. during 1886 and 1887; and at 7 a.m., 9 a.m., 2 p.m., and 9 p.m. during 1888. The following are some of the results for each year:—

| Year. | Temperature. | | | | |
|---|---|---|---|---|---|
| | Mean. | Mean Max. | Mean Min. | Highest. | Lowest. |
| | ° | ° | ° | ° | ° |
| 1886 | 78·0 | 86·0 | 69·9 | 96·0 April 3 | 69·8 July 5 |
| 1887 | 77·2 | 85·4 | 69·0 | ...... | ...... |
| 1888 | 77·2 | 84·3 | 70·1 | 92·5 October 8 | 58·5 March 4 |

| Year. | Sunshine. | Rainfall. | | |
|---|---|---|---|---|
| | Hours. | Total. | No of days. | Greatest fall. |
| | | ins. | | ins. |
| 1886 | 2801·4 | 91·96 | 160 | 6·00 April 4. |
| 1887 | ...... | 65·73 | ... | 5·50 May 16 |
| 1888 | 2431·4 | 85·85 | ... | 4·50 April 27 |

**Meteorologische Zeitschrift.** Redigirt von Dr. J. Hann und Dr. W. Köppen. July-September 1890. 4to.

The principal articles are:—Zusammenfassung der Resultate der Barometervergleichungen von Waldo, Sundell und Brounow, 1883-87; von Dr. W. Köppen (12 pp.). This is a criticism of the results of these three comparisons of standard barometers, which were carried out between 1883 and 1887. It is satisfactory to learn that Dr. Köppen finds that the alleged differences between standard barometers do not exist, and that these instruments all fairly agree together.—Messungen des normalen Potentialgefälles der atmosphärischen Elektricität in absolutem Maasse; von J. Elster und H. Geitel (13 pp.).—Der Wolkenbruch auf der Kii-Halbinsel, Japan, am 19 August 1889; von E. Knipping (11 pp. and 2 plates). This is an account of a terrific fall of rain and consequent devastation by floods which was produced by a slow moving typhoon in the south of the Island of Niphon. At one station, Tanabe, 35·5 ins. fell in 17 hours; three other stations had about half that amount. The number of lives lost was 1,502, and 400,000 people were rendered homeless. The number of trees washed away in one district is estimated at 200,000.—Veränderlichkeit der Tagestemperatur in Japan; von E. Knipping (6 pp.). This discussion shows that the variability of temperature in Japan is moderate, as might be expected from its insular climate.—Ueber wandernde Funken; von F. von Lepel (4 pp.). This is an account of the reproduction of ball lightning, as already announced by Planté in the *Comptes Rendus* for 1875-6. Herr von Lepel has produced them by a simpler process, for which reference must be made to the paper. The appearance of balls indicates a very weak tension, a very slight increase of tension produces a red spark instead of a ball.—Ueber das allgemeine Windsystem der Erde; von W. von Siemens (8 pp.). This is an answer to some remarks of Dr. Sprung's, in the

form of a reprint of Siemens' paper in the *Sitzungsberichte* of the Berlin Academy. It is a purely theoretical paper showing how far the author agrees with Ferrel, or the contrary.—Bemerkungen über die Temperatur in den Cyclonen und Anticyclonen; von Dr. J. Hann (16 pp.). This is a very convincing reply to the utterances of Prof. Hazen in *Science*, who has asserted that all Dr. Hann's statements as to the distribution of temperature with height in mountains are worthless. Dr. Hann, by careful reasoning, shows up Prof. Hazen's mistakes. —Die Veränderlichkeit der Temperatur auf den britischen Inseln, 1869-1883; von R. H. Scott (3 pp.). This is an abstract of Mr. Scott's paper in the *Proceedings of the Royal Society* on the variability of temperature.

PROCEEDINGS OF THE ROYAL SOCIETY. Vol. XLVIII. Nos. 292-294. 8vo. 1890.

Contains: On the barometric oscillations during Thunderstorms, and on the Brontometer, an instrument designed to facilitate their study: by G. J. Symons (9 pp.). During some heavy rains and during some thunderstorms, the barometer rises and falls rapidly and irregularly. In order to ascertain the cause of these variations, the author considers it necessary to determine precisely the sequence of the various phenomena, and the times of their greatest intensity, and for this object he has devised in conjunction with MM. Richard Frères, of Paris, the instrument which he terms a Brontometer, or Thunderstorm measurer. This is provided with endless paper, 12 ins. wide, travelling under the various recording pens at the rate of 1·2 in. per minute, or 6 ft. per hour. The velocity of the wind is continuously recorded by one of Richard's anemo-cinemographs, and the atmospheric pressure by a modified form of their statoscope, which is so delicate as to give 30 inches for each inch of the mercurial barometer. There are mechanical arrangements whereby the observer records: (1) the commencement, variation in intensity, and termination of rain; (2) the instant of each flash of lightning; (3) the commencement and duration of each clap of thunder; and (4) the commencement, variation in intensity, and termination of hail.—On Wind Pressure upon an inclined Surface; by W. H. Dines (25 pp.). This is an account of some experiments made on the large whirling machine at Hersham, somewhat after the plan indicated in Mr. Dines's papers on p. 205 of the present No. of the *Quarterly Journal*.

SYMONS'S MONTHLY METEOROLOGICAL MAGAZINE. Vol. XXV. Nos. 294-296. July-September 1890. 8vo.

Contains among other information the following articles:—Areas of rarefaction or Depressions: by the Rev. G. T. Ryves, Dr. Muirhead, Prof. Hazen, and W. H. Dines (7 pp.).—The great rain of July 17th, 1890 (1 p. and map.).—Phenological Observations (1 p.).—Solar radiation thermometers; by Prof H. McLeod (2 pp.).—Sunburn (3 pp.).—The Climate of Brighton; by F. E. Sawyer (2 pp.).

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THE END.